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Sveučilišni centar Varaždin / University Center Varaždin
Jurja Križanića 31b, 42000 Varaždin, Croatia
Tel. ++385 42 493 338, Fax.++385 42 493 336
E-mail: tehnickiglasnik@unin.hr
https://tehnickiglasnik.unin.hr
https://www.unin.hr/djelatnost/izdavastvo/tehnicki-glasnik/
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Representing the Countries Credit Ranking Problem with a Simple Weighted Non-Linear Formulation

Sadegh Niroomand

Abstract: In this study a non-linear weighted sum model is proposed to rank countries based on economic factors. This ranking problem could be new and useful as most of previous researches rated countries not rank them. The countries are ranked from the best to the worst one by their score obtained by the model from credit point of view. As an advantage of the model, it is solvable by an analytical solution method manually instead of using optimization software. The analytical solution is useful for managers and decision makers to apply the model easily. The obtained ranking is compared with Moody's rating to discuss the efficiency of the model.

Keywords: country credit ranking; country credit rating; non-linear model; weighted additive model

1 INTRODUCTION

Understanding the contribution of economic and political factors on the evaluation of countries credit rating has crucial policy implications. Up to now there are many different methodologies were suggested by researchers to calculate country credit rating (sovereign rating), however some of them were valuable. Most of these approaches and techniques are based on mathematical models ([1-3]) and some the others based on probabilistic and stochastic methods ([4-6]). Famous rating agencies such as Standard & Poor's, Moody's, Fitch Rating, etc. announce a rating list monthly, quarterly, semiannually and annually which rate counties by considering several factors (economic and political). They employ different methodologies and techniques in addition to idea of expertise to rate the countries. In fact, it is impossible to create a unique model to rate countries, since there are many different quantitative and qualitative factors directly or indirectly affecting the outcome.

Credit rating announcement that is provided by the rating agencies affect the financial market in different ways. Recently, information provided by rating agencies is important for market contributors and regulators much more than past as they are under pressure after they fail to predict world financial crises 2007-2008 [7]. The latest crisis demonstrated that the country credit rating is an important issue in the international market for both develop and developing countries [8]. For that reason nowadays credit rating agencies are not the only provider for rating information as econometrician, operation researcher, financial investigator and statisticians, etc. propose valuable approaches to rate countries [9].

Credit rating methods mostly consider some predetermined levels for countries and each country is assigned to an appropriate level. The assignment of each country is done just by evaluation of the performance of that country in the economic factors considered for the rating. On the other hand credit ranking prepare a complete ranking of countries from the best to the worst one according to the economic factors. So, the performances of countries in the economic factors are compared to rank the countries.

In this study a mathematical model is proposed to rank the countries and it is subjected to selected economic factors. The suggested model is used to rank the countries (from best to worst) rather than rating them from credit point of view as the most of researches have focused on countries credit rating. The model calculate counties' score and the countries are ranked based on their obtained score. In other word, the result is subjective to the factors and number of countries which are selected. Therefore, if new counters or factors are selected and added to the dataset, then the ranking result may change accordingly.

As the rest of the paper, Section 2 reviews the existing literature of methodologies and techniques which were utilized in country credit rating. Section 3 proposes a non-linear data envelopment analysis model for countries credit ranking. Data collection and factor selection are discussed in Section 4. Empirical result and comparison of result with Moody's rating is covered by Section 5. Concluding remarks are discussed in the last section.

2 LITERATURE REVIEW

Sovereign rating also known as country rating, is one of the import topics in the global financial market and is affected mostly by economic factors. Up to now, researchers proposed different methodologies which utilize mathematical, statistical, probabilistic and/or stochastic models to rate or classify countries. For instances, a model that is proposed in 2001 was based on the multi-criteria decision aid (MCDA) and multi-group hierarchical discrimination (M.H.DIS), which use different factors to classify a number of countries in to specified classes. The model was revised many times during next 2 years starting from 2000 to 2002 ([1, 2]). Later on, the proposed model have modified and improved by [9] and used to reconstruct the World Bank classification. Ref. [4] constructed rating transition matrices for countries as an input of rating-based credit portfolio model. Ref. [10] applied reverse engineering

by utilizing Logical Analysis of Data in the case of financial risk rating and the results were compared with Standard & Poor's rating result to prove the model accuracy.

One of the important issues in country rating is factors' selection. Although, economic and political factors both have essential effect on the country credit rating result, many economic theories emphasis in importance of macroeconomic factors for credit and default rating of countries [11]. It seems instinctively obvious that macroeconomic conditions of a country should effect on the credit rating of that country [12]. The relations between macroeconomic factors and risk default were examined by several researchers such as [13-17], and so on. The macroeconomic factors which appear to be significant for country credit rating are GDP, GDP per capita and GDP growth ([18-21]), current account balance and public [22] and debt budget balance [23]. Later, [24] mentioned that six factors appear to be important in deciding about country credit rating. Those six factors are GDP per capita, external debt, level of economic development, default history, real growth rate and inflation. Ref. [25] investigated the impact of worldwide financial conditions, domestic fundamentals and U.S. macroeconomic factor (news) on the emerging market bond index spread based on daily data. They found out that in the long run evolution of emerging market bond index spread is affected by global financial conditions, crises and domestic fundamentals which depend on sovereign rating. Ref. [26] investigated on the interactions between sovereign ratings and macroeconomic factors using a Panel Vector Autoregressive (PVAR) approach. He used annual data for European countries from 1996-2013. The results of the study proved that there is a significant tow-way interaction between macroeconomic factors and sovereign rating. Ref. [27] studied the impact of tax convexity on the decisions taken for investing purposes.

Based on the information in the literature, several economic factors are chosen for this study which are discussed in Section 4.1.

3 THE PROPOSED MODEL

In this section a mathematical model is introduced to rank some given countries according to some criteria (economic factors) in a way that the countries with higher ranking provide better environment for making investment by investors. The model applies the following notations and their definitions:

I - number of countries to be ranked (parameter),
J - number of criteria (economic factors) that effect ranking obtained for the countries (parameter),
i - index used to show each country (index),
j - index used to show each economic factor (index),
w_j - relative importance obtained for the j^{th} economic factor (variable),
S_i - maximal possible score obtained for country i (variable),
x_{ij} - performance of country i in economic factor j (parameter),
r_{ij} - normalized performance of country i in economic factor j (parameter).

As the economic factors are divided to two types of positive (factors that higher performance of them is favored e.g. income) and negative (factors that lower performance of them is preferred e.g. inflation rate) factors, the normalization of x_{ij} is obtained by,

$$\begin{cases} r_{ij} = \dfrac{x_{ij} - \min\limits_{i=1,2,...,I}\{x_{ij}\}}{\max\limits_{i=1,2,...,I}\{x_{ij}\} - \min\limits_{i=1,2,...,I}\{x_{ij}\}} & \text{if } j \in POS \\ r_{ij} = \dfrac{\min\limits_{i=1,2,...,I}\{x_{ij}\} - x_{ij}}{\max\limits_{i=1,2,...,I}\{x_{ij}\} - \min\limits_{i=1,2,...,I}\{x_{ij}\}} & \text{if } j \in NEG \end{cases} \quad (1)$$

where POS and NEG are the sets of positive and negative economic factors, respectively.

Assuming that the factors are allowed to have positive relative importance such that $w_1, w_2, \ldots, w_J \geq 0$, the aim is to aggregate multiple performance scores of each country obtained from different factors into a single score for the credit ranking problem. Therefore, a country with the highest score is ranked at the first place and so on.

To achieve this purpose, the following weighted sum model is proposed,

$$\max S_i = \sum_{j=1}^{J} r_{ij} w_j, \quad (2)$$

subject to

$$\sum_{j=1}^{J} w_j^2 = 1, \quad (3)$$

$$w_j \geq 0,\ j \in \{1, 2, ..., J\} \quad (4)$$

The model (2)-(4) is applied to each country separately. The objective function calculated by Eq. (2) is a simple weighted sum of the normalized performances of each country in all the factors which maximizes the possible score obtained for the country. In constraint (3), the Euclidean norm of the relative importance of the factors is equal to 1. Applying this constraint, the model is an endogenous type model. Meaning that the relative importance of each factor is determined by the data of the model (normalized performances) endogenously instead of being determined by a decision maker. Constraint set (4) guarantee a positive weight for each factor.

Using Euclidean norm in the constraint (3) is an advantage for the model which gives a possibility to the model to be solved analytically. Thus, any financial manager and decision maker can apply and solve the model manually without any optimization solver. The analytical optimal solution of the model can be obtained by the method of Lagrange multipliers.

A simple explanation of Lagrange multipliers method can be found in the following steps:

Step 1: A model to be solved: max $f(x)$ s.t $g(x) = c$

Step 2: Construct an auxiliary function: $\Lambda(x, \lambda) = f(x, \lambda) + \lambda[g(x) - c]$

Step 3: Solve equation $\nabla_{x,\lambda}\Lambda(x,\lambda)=0$ to obtain optimal value of x.

To apply the Lagrange multipliers method to the model (6)-(8), first the Lagrange function Λ is defined by,

$$\Lambda(w_1, w_2, ..., w_J, \lambda) = \sum_{j=1}^{J} r_{ij} w_j + \lambda\left(\sum_{j=1}^{J} w_j^2 - 1\right) \quad (5)$$

Then, $\nabla_{w_1, w_2, ..., w_J, \lambda}\Lambda(w_1, w_2, ..., w_J, \lambda) = 0$ implies that,

$$\frac{\partial\Lambda}{\partial w_j} = 0 \quad j \in \{1, 2, ..., J\} \quad (6)$$

so,

$$w_j = \frac{-r_{ij}}{2\lambda} \quad j \in \{1, 2, ..., J\} \quad (7)$$

and

$$\frac{\partial\Lambda}{\partial\lambda} = 0 \quad (8)$$

so,

$$\lambda = \pm\frac{\sqrt{\sum_{j=1}^{J} r_{ij}^2}}{2} \quad (9)$$

Replacing (14) in (12) results in the multiple optimal solution of the model (6)-(8) by,

$$w_j^* = \begin{cases} \dfrac{r_{ij}}{\sqrt{\sum_{j=1}^{J} r_{ij}^2}} \\ \dfrac{-r_{ij}}{\sqrt{\sum_{j=1}^{J} r_{ij}^2}} \end{cases} \quad j \in \{1, 2, ..., J\} \quad (10)$$

Considering constraint (8), the optimal analytical solution for the model (6)-(8) for each country is obtained by the following equation for each country.

$$w_j^* = \frac{r_{ij}}{\sqrt{\sum_{j=1}^{J} r_{ij}^2}} \quad j \in \{1, 2, ..., J\} \quad (11)$$

Finally, applying (16) in (6), the optimal (maximum) score for each country is obtained by the following equation.

$$S_i^* = \sum_{j=1}^{J} r_{ij} w_j^* = \sum_{j=1}^{J} \frac{r_{ij}^2}{\sqrt{\sum_{j=1}^{J} r_{ij}^2}} \quad i \in \{1, 2, ..., I\} \quad (12)$$

4 COMPUTATIONAL EXPERIMENTS ON A CASE STUDY

In this section the efficiency of the proposed model (2)-(4) and its analytical optimal solution obtained by (11) and (12) is measured. Some economic factors and countries are considered to be raked accordingly. Finally some economical comments on the obtained ranking are discussed.

4.1 Data Collection and Modification

All data in this study were collected from International Monetary Fund (IMF) database. Totally 25 factors (economical) and 53 countries are selected to elaborate the approximate ranking method. The number of selected countries is depended to availability of information in IMF database 2014. In addition, information related to the local currency rating of Moody's investor service (government bond rating for August 2014) is used to compare with the result of the proposed model. The 25 economic factors are listed in Tab. 1.

Table 1 Economic factors selected from IMF database

Factor Number	Factor Name and Type
1	Gross domestic product, constant prices (positive)
2	Gross domestic product, current prices (positive)
3	Gross domestic product based on purchasing-power-parity (PPP) valuation of country GDP (positive)
4	Gross domestic product based on purchasing-power-parity (PPP) per capita GDP (positive)
5	Gross domestic product per capita, current prices (positive)
6	Gross domestic product based on purchasing-power-parity (PPP) share of world total (positive)
7	Total investment (positive)
8	Gross national savings (positive)
9	Volume of exports of goods and services (positive)
10	General government revenue (positive)
11	General government total expenditure (positive)
12	General government net lending/borrowing
13	Current account balance ($)(positive)
14	Current account balance (percentage of GDP) (positive)
15	Volume of exports of goods (positive)
16	General government primary net lending/borrowing (positive)
17	Inflation, average consumer prices (index) (negative)
18	Inflation, average consumer prices (percentage change) (negative)
19	Inflation, end of period consumer prices (index) (negative)
20	Inflation, end of period consumer prices (percentage change) (negative)
21	Volume of imports of goods and services (negative)
22	Volume of Imports of goods (negative)
23	Unemployment rate (negative)
24	General government gross debt (negative)
25	Gross domestic product, deflator (negative)

The performance of each country in each economic factor (x_{ij}) also is obtained from IMF database. The x_{ij} values of all countries in all 25 selected factors are normalized (r_{ij}) by the method mentioned in Eq. (1). The obtained r values of two factors (for instance) of Tab. 1 for all countries are depicted in Tabs. 2 and 3.

4.2 Credit Ranking of the Countries

After normalizing the performances of each country in all factors, the model (2)-(4) is solved separately for each country using its analytical solution. The countries are sorted

by decreasing order of their optimal scores. The ranking obtained for the countries is illustrated by Tab. 4.

Table 2 The selected countries and original and normalized values of their performances in a positive factor for instance.

Country	Factor 1 (Positive Factor) Gross domestic product, constant prices		Country	Factor 1 (Positive Factor) Gross domestic product, constant prices	
	x_{ij}	r_{ij}		x_{ij}	r_{ij}
Albania	2.1	0.213252315	Kazakhstan	5.672	0.730034722
Australia	2.623	0.288917824	Korea	3.709	0.44603588
Austria	1.693	0.154369213	Kuwait	2.559	0.279658565
The Bahamas	2.297	0.241753472	Latvia	3.772	0.455150463
Belgium	1.22	0.0859375	Malaysia	5.2	0.661747685
Belize	2.5	0.271122685	Morocco	3.908	0.474826389
Bulgaria	1.6	0.140914352	Netherlands	0.832	0.029803241
Canada	2.299	0.242042824	New Zealand	3.254	0.380208333
Chile	3.634	0.435185185	Norway	1.791	0.168547454
China	7.538	1	Pakistan	3.102	0.358217593
Colombia	4.488	0.558738426	Panama	7.201	0.951244213
Costa Rica	3.8	0.459201389	Peru	5.519	0.707899306
Denmark	1.481	0.123697917	Philippines	6.468	0.845196759
Egypt	2.256	0.235821759	Poland	3.088	0.35619213
Estonia	2.361	0.251012731	Portugal	1.166	0.078125
France	1.03	0.058449074	Romania	2.243	0.233940972
Germany	1.709	0.156684028	Russia	1.327	0.101417824
Honduras	3	0.343460648	Singapore	3.625	0.433883102
Hong Kong SAR	3.747	0.451533565	Slovak Republic	2.299	0.242042824
Hungary	1.984	0.196469907	South Africa	2.344	0.248553241
Iceland	2.682	0.297453704	Sweden	2.769	0.310040509
Ireland	1.699	0.155237269	Thailand	2.495	0.270399306
Israel	3.235	0.377459491	Tunisia	3	0.343460648
Italy	0.626	0	Turkey	2.267	0.237413194
Jamaica	1.275	0.093894676	United Kingdom	2.878	0.325810185
Japan	1.351	0.104890046	United States	2.768	0.309895833
Jordan	3.5	0.415798611	Uruguay	2.786	0.3125

Table 3 The selected countries and original and normalized values of their performances in a negative factor for instance.

Country	Factor 25 (Negative Factor) Gross domestic product, deflator		Country	Factor 25 (Negative Factor) Gross domestic product, deflator	
	x_{ij}	r_{ij}		x_{ij}	r_{ij}
Albania	204.797	0.913024625	Kazakhstan	215.747	0.904545909
Australia	101.95	0.992660296	Korea	118.852	0.979572874
Austria	117.278	0.980791641	Kuwait	243.694	0.882906210
The Bahamas	107.017	0.988736857	Latvia	112.598	0.984415422
Belgium	104.406	0.990758586	Malaysia	130.816	0.970309005
Belize	121.377	0.977617736	Morocco	126.58	0.973588991
Bulgaria	144.92	0.959388108	Netherlands	111.796	0.985036420
Canada	112.79	0.984266754	New Zealand	153.197	0.952979127
Chile	124.58	0.975137615	Norway	108.568	0.987535899
China	325.875	0.819272472	Pakistan	252.684	0.875945145
Colombia	148.576	0.956557223	Panama	150.013	0.955444536
Costa Rica	1,047.64	0.260401140	Peru	227.205	0.895673841
Denmark	120.123	0.978588723	Philippines	178.292	0.933547766
Egypt	318.813	0.824740664	Poland	123.604	0.975893343
Estonia	149.611	0.955755810	Portugal	108.683	0.987446853
France	115.045	0.982520680	Romania	185.687	0.927821729
Germany	111.958	0.984910981	Russia	165.187	0.943695125
Honduras	227.674	0.895310689	Singapore	105	0.990298644
Hong Kong SAR	108.606	0.987506475	Slovak Republic	110.846	0.985772016
Hungary	135.014	0.967058443	South Africa	179.978	0.932242276
Iceland	202.286	0.914968923	Sweden	101.45	0.993047452
Ireland	101.638	0.992901882	Thailand	240.79	0.885154812
Israel	110.766	0.985833961	Tunisia	148.64	0.956507667
Italy	115.471	0.982190823	Turkey	1,383.94	0
Jamaica	214.183	0.905756933	United Kingdom	108.226	0.987800714
Japan	92.471	1	United States	108.216	0.987808457
Jordan	230.443	0.893166619	Uruguay	191.055	0.923665222

4.3 More Discussion on the Obtained Ranking

It appears that country rating remain an important determinant of agencies credit rating. Although this study used a non-linear ranking model to rank the countries, it can be even used as an approach to rate countries. The model try to compare all countries by each other base on all economic factor levels, and rank the countries from the highest score to lowest score. Such a measure is suited for any country that have available information regarding to those economic factors.

The results that are depicted in Tab. 4 compare 54 countries, and rank them from the highest score to the lowest one. As it is expected, developed countries in Europe, China and US are listed among the top 10 countries. This is a valuable result and reflect the accuracy of the model in ranking the countries. If we compare our results with Moody's rating which is illustrated in Tab. 5, it can be concluded that the ranking model was successful in application. Also it is important to remind that the model which is utilized in this study is used to rank the countries not rating them. Since all of the rating agencies rate the countries and none of them rank them, there is no other source to compare the result of this study with them. Although, there are some miss ranking or error in ranking the model, overall result satisfy and show validity of the model. The reason for miss ranking may occur due to some political factors which were not the interest of this research. Since all of the factors which employed in this study are economic factors and are quantitative, another reason that may be cause of the miss ranking is lake of availability of some economic or other quantitative factors. In addition, as another reason of the miss ranking, some rating agencies are not willing to downgrade some countries since some of them are their clients and many other reasons that are not interest of this research.

One important note that was also mentioned earlier is that the model rank the countries not rate them. So, some time there is a small difference between two or more different ranks. For instance, Sweden and Singapore are ranked in 6th (with score 3.239604525) and 7th (with score 3.234437298) respectively in Tab. 4. Clearly, there is a minor difference between the scores of two countries, but with a small difference Sweden is preferred to Singapore.

Table 4 Complete credit ranking of the countries obtained by the model (2)-(4).

Country	Score (S_i^*)	Obtained Rank	Country	Score (S_i^*)	Obtained Rank
Kuwait	3.691875294	1	New Zealand	2.886315808	28
Norway	3.480280683	2	Iceland	2.873243364	29
China	3.437855554	3	Portugal	2.858175795	30
United States	3.303663530	4	Chile	2.850289140	31
Australia	3.267500871	5	Slovak Republic	2.846360342	32
Sweden	3.239604525	6	Colombia	2.844780097	33
Singapore	3.234437298	7	Estonia	2.841706490	34
Germany	3.200642842	8	Panama	2.829547343	35
Denmark	3.179865668	9	Poland	2.824456333	36
Netherlands	3.160279787	10	Romania	2.806000468	37
Austria	3.113361836	11	Philippines	2.797381073	38
Belgium	3.086349456	12	Morocco	2.764841354	39
France	3.062138820	13	Uruguay	2.748532632	40
Canada	3.036992008	14	The Bahamas	2.720146396	41
Italy	3.033524620	15	Belize	2.718025531	42
Korea	3.031142269	16	Kazakhstan	2.710471842	43
Malaysia	3.022203108	17	Turkey	2.689606545	44
Ireland	2.988980148	18	Albania	2.689481653	45
Hong Kong SAR	2.987219531	19	Jordan	2.668579912	46
Israel	2.981351300	20	Tunisia	2.572606402	47
Bulgaria	2.941056949	21	Costa Rica	2.458448512	48
United Kingdom	2.935241441	22	Pakistan	2.449036743	49
Thailand	2.916347181	23	South Africa	2.439498125	50
Hungary	2.903752619	24	Honduras	2.409879802	51
Peru	2.899935046	25	Russia	2.303064757	52
Latvia	2.896582265	26	Jamaica	2.177198077	53
Japan	2.895213607	27	Egypt	2.082532847	54

5 CONCLUSION

Country credit rating changes have influences on investment and every sector of the related countries. Most of researches in the literature focus on rating changes of countries and those rating affected mostly by macroeconomic outcomes. Numerous downgraded of European countries in past years have shown how vital it is to examine the issue.

This study starts for the first time to rank a set of countries based on several important macroeconomic factors instead of rating them. A weighted sum model was proposed and solved analytically. The analytical optimal solution was obtained by the Lagrange Multipliers method easily. This easy solution method is an advantage of the model that helps the managers to apply the model easily without any optimization software. The results was compared to Moody's rating (in 2013) to show accuracy of the model. This study is a worthy empirical analysis for comparing several specified countries for investment. In particular, if there is a set of specified countries which are interested for investment, it is possible to compare them and find the best candidate. The presented model can be an alternative to country risk rating

of agencies, since there is a broad question agency variation in credit quality assessment in the country perspective.

Table 5 Moody's rating for 54 countries

Country	Moody Scale	Country	Moody Scale	Country	Moody Scale
Kuwait	Aa2	Hong Kong SAR	Aa1	Romania	Baa3
Norway	Aaa	Israel	A1	Philippines	Baa3
China	Aa3	Bulgaria	Baa2	Morocco	Ba1
United States	Aaa	United Kingdom	Aa1	Uruguay	Baa2
Australia	Aaa	Thailand	Baa1	The Bahamas	Baa1
Sweden	Aaa	Hungary	Ba1	Belize	Caa2
Singapore	Aaa	Peru	A3	Kazakhstan	Baa2
Germany	Aaa	Latvia	Baa1	Turkey	Baa3
Denmark	Aaa	Japan	Aa3	Albania	B1
Netherlands	Aaa	New Zealand	Aaa	Jordan	B1
Austria	Aaa	Iceland	Baa3	Tunisia	Ba3
Belgium	Aa3	Portugal	Ba1	Costa Rica	Baa3
France	Aa1	Chile	Aa3	Pakistan	Caa1
Canada	Aaa	Slovak Republic	A2	South Africa	Baa1
Italy	Baa2	Colombia	Baa2	Honduras	B3
Korea	Aa3	Estonia	A1	Russia	Baa1
Malaysia	A3	Panama	Baa2	Jamaica	Caa3
Ireland	Baa1	Poland	A2	Egypt	Caa1

Future studies on the country credit ranking problem may focus on using linear data envelopment analysis models to rank countries. On the other hand simultaneous countries credit rating-ranking problem may be an interesting study.

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Author's contacts:

Sadegh Niroomand
Department of Industrial Engineering,
Firouzabad Institute of Higher Education, Firouzabad, Fars, Iran
E-mail: sadegh.niroomand@yahoo.com
Phone: 0098 917 826 9032

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Analyzing the Human Blood Glucose Level Trend (Up or Down) by Using Optical Polarization

Ercan Mengüç*, Selçuk Helhel

Abstract: Large amount of people having diabetics in the world, and it is increasing very rapidly. Diabetics should to check their blood glucose level at least four times a day. When controls are not done regularly, risk of hypoglycemia and hyperglycemia may arise. There are ongoing researches for developing non-invasive methods as an alternative to finger piercing, which is the most commonly used and painful method for patients. In this study, although a physical glucometer design has not been completed yet, it has been demonstrated which wavelength ranges and which parameters can be used for non-invasive device. Most importantly an empirical relationship has been established between the level of blood sugar and de-polarization disturbance seen in circularly polarized light. The proposed equation can estimate the blood glucose level based on de-polarization information with an average error rate of 1%.

Keywords: blood glucose; depolarization; glucose; non-invasive; polarization of light; tissue

1 INTRODUCTION

In diabetes, pancreas cannot produce enough insulin or produced insulin cannot be used effectively. Diabetes is divided into two categories as Type-1 and Type-2. Type 1 diabetes (previously known as insulin-dependent) is characterized by insufficient insulin production and requires daily need of insulin. Type-2 diabetes have a combination of insulin secretion disorders and insulin resistance. Type-2 represents more common diabetes disease.

Hypoglycemia and hyperglycemia are two negative sides of diabetes that need to be avoided. Those can be under control by regular measurements. Diabetics have to keep their blood sugar levels under control. To achieve this, patients must measure their glucose level up to 6 times a day. There are three different methods to detect blood glucose level. These are invasive, minimally invasive and non-invasive. The most widely used method is an invasive one and in that method some blood is taken out of the body with a needle and measurements are made. This way comparatively expensive and they are not practical for kids' usage. In second method; there is still a needle which also embedded in the patient's body. At third method measurements are taken without taking blood out of the body. Therefore, patients do not feel pain.

It is a known fact that the light is a special form of an electromagnetic wave. Light that falls on human body is absorbed, scattered, reflected or transmitted. Mentioned light events contain information about medium.

Increased glucose ratio makes blood more homogeneous and the polarization information observed from medium is high enough. That homogeneity causes less scattering and absorption events; this situation typically results in stable polarization information. It is proved/shown by using analysis and graphics at section 3. Proposed empirical model can predict blood glucose levels concerning the polarization distortion with an average error rate of 1%.

Different methods and techniques on non-invasive glucose level measurements have been studied during the past. But there is no commercial product has produced in market yet. According to the literature and market review, studies are mostly at the beginning phase [1]. In literature; one may find optical techniques [2-4]; MIR (middle infrared), NIR (near-infrared) and Raman spectroscopy techniques [5-7]; techniques using electromagnetic field measurement [8-10]; bio-impedance technique [11, 12]; photo-acoustic method [13]; non-enzymatic sensor applications for determining glucose level [14]; and techniques based on polarization measurements [15-17]. All methods have problems such as insensitivity to glucose measurement and accuracy.

Before analysis, optical properties of human skin and blood are added to optical design platform. All simulations are performed on optical simulation program. During simulation, changes in the flow rate, fluidity and temperature changes of the blood are ignored. In real life, these parameters must be studied and checked furthermore, since these parameters vary from person to person. Parallel to high technological developments, it is expected to that this technology will be miniaturized and will start to be used by patients. Most important aspect of the proposed method makes it possible to predict whether or not the diabetic patient trends of hypoglycemia or hyperglycemia. Furthermore, it is possible to produce pre-warning alarm for patients if the predetermined values are reached.

Details of polarization techniques are given in Section 2, design methods and modeling are in Section 3, results are in Section 4 and conclusion is given in final section.

2 POLARIZATION INFORMATION

When any optically active sample is exposed to a polarized light, some rotational changes occur in polarization information. Rotational change is called optical de-polarization. These changes (optical depolarization) can be measured by polarimeter and provide important information about chemical and physical structures of substances [18, 19]. Change of polarization information from circular to elliptical state allows us to calculate the de-polarization ratio. So we can estimate the trend of blood glucose level either increasing or decreasing. For this aim, model is generated in the simulation platform. In simulation, optical

properties of both blood and skin are added in the model. Circularly polarized light at 600-800 nm wavelength region is sent to the modeled biological tissue and elliptical polarized light is obtained on the other side of the tissue.

Fig. 1 shows the structure of a typical polarimeter. It consists of two polarizers such that one of them is stationary and the other one is rotating. When polarized light passes through an optically active substance, initial polarization state changes rotationally. These rotational change indicates that activity of the optical substance. This activity allows us to determine the molecular size, concentration and purity of the substances.

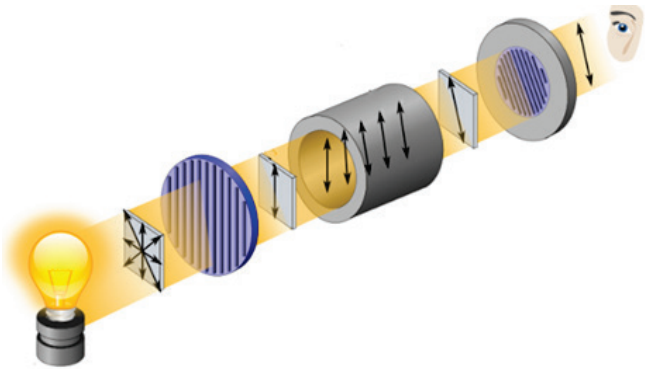

Figure 1 Polarization measurement

Most biological tissues have an anisotropic structure. Because tissues have organic and inorganic molecules with different refractive index values in same environment. Different refractive indices are caused important property called birefringence that distorts polarization information. De-polarization information manifests itself as a phase delay at tissue output. 90% of the phase delay in tissues with a depth of several hundred micrometers is thought to be the result of birefringence.

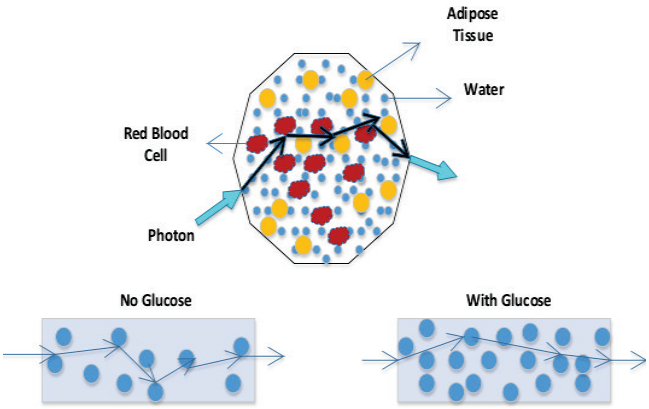

Figure 2 Photon movement

In Fig. 2, it is possible to see how glucose changes the propagation of the light. It is predicted that as the glucose level in the environment increases, both the possibility of light scattering and the optical path decrease, and therefore absorption event in environment decreases. The resulting de-polarization rate increases due to poor absorption. It means that polarization information is preserved. Therefore, if glucose ratio is high enough, de-polarization event within the tissue will be poor and polarization information at tissue outlet will be quite similar to the original polarization information. Mentioned situation is proved by simulation analysis and showed in section 3.

Blood is a structure consisting of plasma and blood molecules. Plasma consists of water, proteins, glucose, and other water-soluble substances, and it constitutes approximately 55% of blood. Although there is an increase in glucose level in blood plasma, hemoglobin concentration, absorption coefficient and refractive index values of blood molecules stay constant. Increased glucose level in blood only changes the density of plasma [21]. The most important change here is the reduction of the refractive index difference between blood molecules and blood plasma. Thus, possibility of scattering and absorption events in blood is reduced. That's why, obtaining polarization information will be easier [21-23].

First step to calculate the de-polarization information is creating simple models of biological tissues. All data is obtained from literature to create models of both human blood and skin. While creating the models, blood flow rate, viscosity and temperature parameters were neglected, and the values of the healthy person dates are used. Polarization measurements of the light passing through the tissue are made in the optical design program. Polarization analysis functions and Stokes parameters of the program are used. Finally, biological model is illuminated with a circularly polarized light wave and an elliptical polarized light wave is obtained at the other side of tissue.

Polarization ellipse used in the optical design program takes into account only E_x and E_y components, while neglecting the E_z component. Polarization ellipse is shown in Fig. 3.

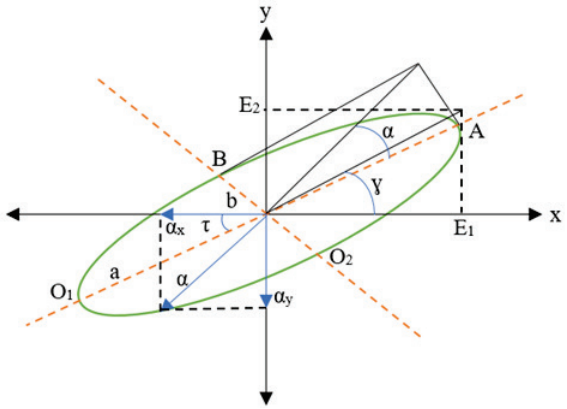

Figure 3 Polarization ellipse

After the polarized light wave is sent to the optically active substance simulator runs the polarization state analysis feature by investigating each photon present in the light. Depending on the type and concentration of the molecules circular polarization information is de-polarized and converted to elliptically polarized light.

Degree of elliptic polarization is calculated by using Eq. (1) and Eq. (2). Amount of rotation in conversion from

circular polarization to elliptical polarization varies depending on the molecular concentration of the particles. For any de-polarization event in optically active substances, the ɣ value shown in Eq. (1) and the δ value in Eq. (2) are the best coefficients used to express the polarization state. Alternatively, α and τ can also be used to describe the polarization state [2].

$$\gamma = \frac{1}{2}\cos^{-1}\cdot\left[(\cos 2\alpha)\cdot(\cos 2\tau)\right], \tag{1}$$

$$\delta = \tan^{-1}\left[\frac{(\tan 2\alpha)}{(\tan 2\tau)}\right]. \tag{2}$$

3 MODELLING AND TESTİNG

600-800 nm wavelength region is considered to be suitable for optical estimation of blood glucose level. In the mentioned region, changing in plasma-derived de-polarization information is negligible and the initial polarization information is largely preserved. Thus, changes in this region are only expected due to glucose levels. The reasons for choosing this region are given below;

1) Absorption and scattering coefficients arising from blood molecules and plasma in the 600-800 nm region are low and the anisotropy factor is in the range of 0.98 and 1.
2) Hemoglobin covers approximately 40 - 50% of the total blood amount and the absorption value from hemoglobin is low in this region.
3) Refractive index mismatch value of hemoglobin between glucose and other molecules is low. In addition, after about 600 nm the refractive indices of Oxy and de-oxy hemoglobin are approximately equal and it's overlapped. This shows that the saturation of blood with oxygen will not affect the measurement results.
4) Approximately 50-60% of blood consists of plasma. ~90% of plasma consists of water. In this region, water-related absorption and scattering events are low.
5) Low absorption coefficients caused by epidermis layer.

Optical coefficients of human skin and blood are obtained from the literature and inserted to the optical design program. The aforementioned expectations have been satisfied. Absorption and scattering parameters from blood molecules and plasma are less in this region. Besides, the anisotropy factor is observed as 0.98-1 in the 600-800 nm range. Therefore, light in this wavelength region will mostly be affected by glucose levels.

The performance tests are given to prove either the mentioned wavelength region is suitable or not. When a circularly polarized light at 100 nm wavelength is sent through an optical environment where there is no biological tissue in the model, there is no depolarization event (100% transmission) at the outlet (Fig. 4).

Optical properties of biological tissues are added into the model for observing their effects, and transmission ratio drops down to 12.86% concerning initial conditions (Fig. 5). Fig. 5 shows that the photon has lost its energy by encountering to high absorption and scattering at the specified wavelength.

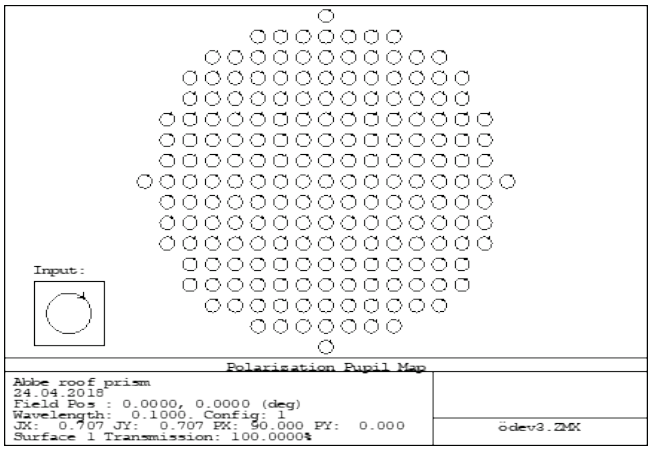

Figure 4 Circularly polarized light at 100nm wavelength

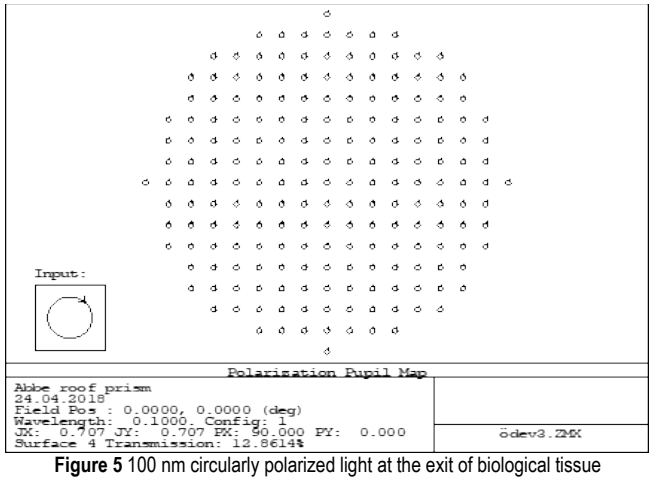

Figure 5 100 nm circularly polarized light at the exit of biological tissue

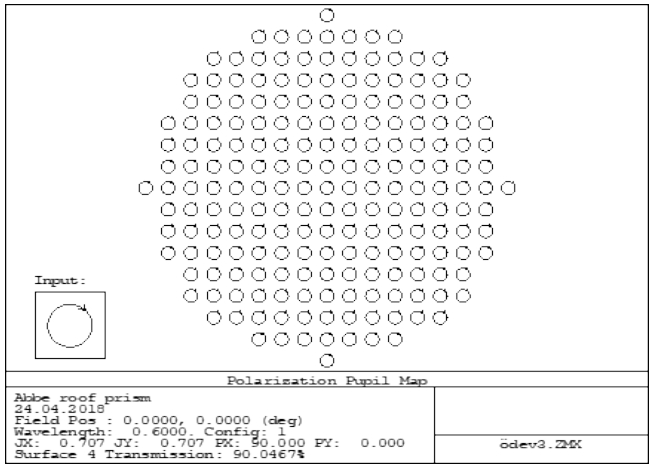

Figure 6 600 nm circularly polarized light at the exit of biological tissue

For the next step, applied wavelengths are changed to 600 nm and 800 nm. At 600 nm and 800 nm, transmission values increase up to 90% and 94%, respectively (Fig. 6 and Fig. 7). These results prove the accuracy of the items described at the beginning of Chapter 3 and tell us we may

use this wavelength interval. As obtained from Fig. 6 and Fig. 7, de-polarization level in this wavelength region is low and polarization information is high enough to make the analysis. In this way, changes in glucose level can be observed more easily only in this region. Other components that can be mask the change in the polarization information that is not sourced by glucose are less in mentioned region.

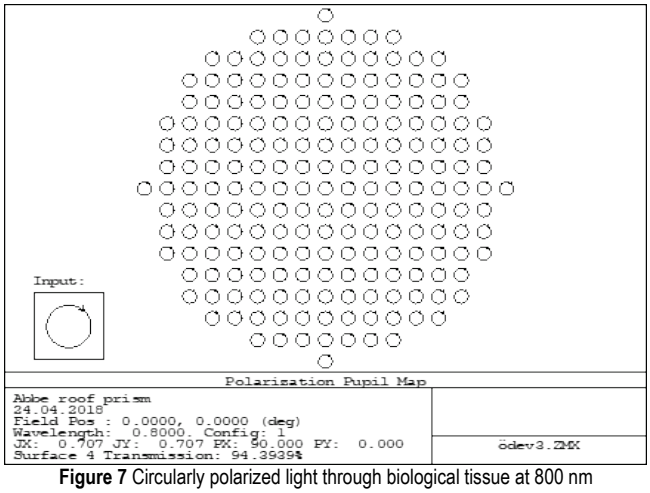

Figure 7 Circularly polarized light through biological tissue at 800 nm

Finally, by combining all results 600-800 nm region seems suitable for operating wavelengths. Afterward, de-polarization information will obtain with respect to different glucose level.

4 RESULTS

By using optical design program, polarization information that transmitted through the tissue at different glucose ratios in the 600-800 nm region is measured. Eq. (1) and Eq. (2) are used to calculate degrees of polarization.

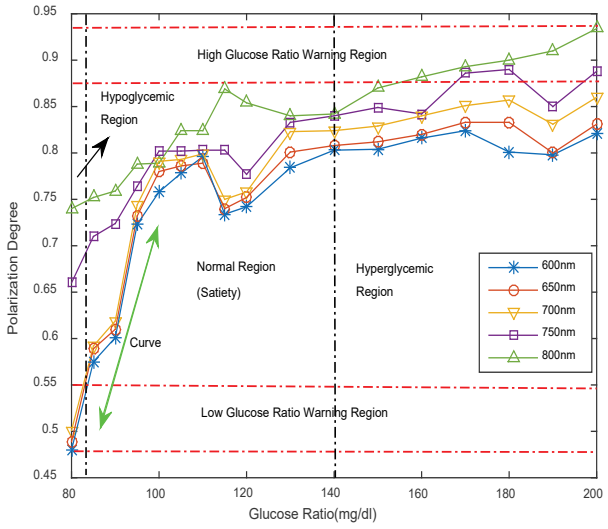

Figure 8 Polarization degree for different wavelength concerning different glucose level (80-200 mg/dl)

Finally, different degrees of polarization state are obtained for different wavelengths. Fig. 8 shows the change in polarization degree according to five different wavelengths and varying glucose level. The treated wavelengths are 600 nm, 650 nm, 700 nm, 750 nm, and 800 nm. Normally, glucose level above 120 mg / dl is considered high, especially in Type-1 patients, this value can be up to 180 mg/dl. Therefore, this expanded region can be used to derive a mathematical model. From these graphs, it is seen that the wavelengths of 600 nm, 650 nm, and 700 nm are very close to each other. And it can be established linear relationship for a glucose level between 80 mg/dl and 100 mg/dl (Green line in Fig. 8).

Tab. 1 demonstrates average mean error and median error of five different wavelengths. Minimum errors of the median specified in Tab. 1 are shown in bold. Minimum errors are at 600 nm, 650 nm, and 700 nm. With help of Table 1, 600 nm, 650 nm, and 700 nm are grouped for generating mathematical models. Also smoothing function is applied on plots. The proposed mathematical model is expressed in Eq. (3). Coefficients of Eq. (3) and their meanings are tabulated in Tab. 2.

Table 1 Calculated Mean and Median Errors

Wavelength	Mean (rmse)	Median (rmse)
$error_{600\ nm}$	0.0441	0.0275
$error_{650\ nm}$	0.0351	0.0169
$error_{700\ nm}$	0.0259	4.85e-04
$error_{750\ nm}$	0.0344	0.0586
$error_{800\ nm}$	0.0696	0.0935

$$P(x) = a_1 \cdot \mathrm{e}^{-\left(\frac{x-b_1}{c_1}\right)^2} + a_2 \cdot \mathrm{e}^{-\left(\frac{x-b_2}{c_2}\right)^2}. \quad (3)$$

Table 2 Coefficients of Eq. (3)

x	Glucose Ratio (mg/dl)	SSE	0.002514
$P(x)$	Polarization Degree	R-square	0.9851
a_1	0.8646	Adjusted R-square	0.9783
a_2	0.2053	RMSE	0.01512
b_1	179.7	b_2	102.2
c_1	115.4	c_2	27.21

In Fig. 9, measured values and the response of the proposed model are shown together. It is seen that proposed model is quite sensitive and has the potential to respect the glucose level [24, 25].

In addition, an equation is created in range where the glucose level is 80-100 mg/dl only to prevent situations caused by the hypoglycemic state. This equation is showed at Eq. (4). Because, as seen in Fig. 8 (green line), this region has a linear relationship with the glucose level and degree of polarization. A sensor using this relationship can be designed much more easily.

$$y = 0.0144 \cdot x - 0.65 \quad (4)$$

where x = glikoz oranı and y = polarizasyon derecesi.

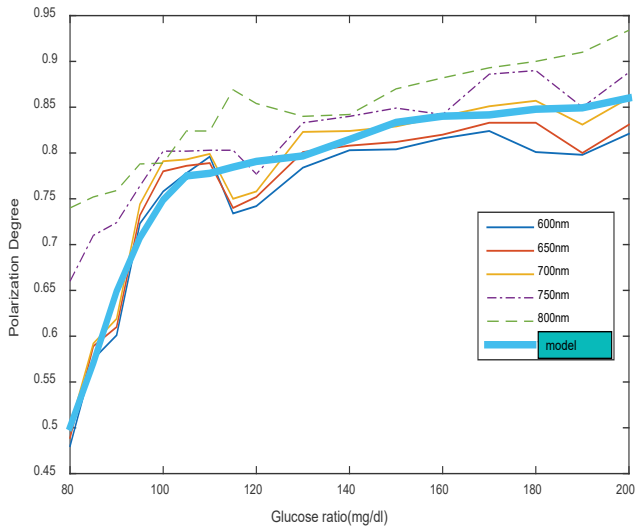

Figure 9 Fitting curve obtained from the median curve of the sum of curves of different glucose and wavelengths

5 CONCLUSION

In this study, estimation of human glucose level is investigated. By using polarization techniques light transmitted through modelled biological tissue is examined. Skin, blood, and glucose models are used in the optical design program. Skin, blood, and glucose are created by using optical coefficients (absorption, scattering, reflection, transmission, and anisotropy) obtained from various sources in the literature.

Optical method is proposed to estimate the glucose level in human blood and a potential working wavelength window is proposed. This window is between 600 to 700 nm. It is shown by simulation results that window is suitable. In order to determine this window most accurately, all components of blood and skin such as hemoglobin, melanin, skin, and plasma must be taken into consideration. Effects of these components can be examined in further academic studies.

A mathematical model predicting the trending tendency of increasing and decreasing glucose levels is proposed. The proposed mathematical (empirical) model can predict blood glucose levels despite the polarization distortion with an average error rate of 1%. This proposed mathematical model makes it possible to create a monitoring and warning system for diabetic if it is integrated with sensor. It will be possible to predict whether the diabetic patient tends hypoglycemia or hyperglycemia. So, it is possible to produce pre-warning alarm for the patient if the predetermined values are reached.

In future, firstly, obtained results taken from this work must be done in vivo. Secondly, all this work can be turned into a portable device that patients can use. Finally, focusing on concepts related to how to increase accuracy, how to eliminate distorting effects, how to set up a powerful calibration model, how to increase low SNR rates, and how to design miniature device.

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Authors' contacts:

Ercan Menguc, PHD student
(Corresponding author)
Akdeniz University,
Department of Electrical and Electronics Engineering,
Dumlupınar Bulvarı, Antalya, Turkey
+90-05455562077, ercanmenguc@gmail.com

Selcuk Helhel, Professor
Akdeniz University,
Department of Electrical and Electronics Engineering,
Dumlupınar Bulvarı, Antalya, Turkey
+90-05055052239, selculhelhel@akdeniz.edu.tr

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The Nexus between Energy Consumption Shocks and Economic Growth: Using BVAR Approach

Ezatollah Abbasian*, Salaheddin Manochehri

Abstract: This paper examines the nexus between economic growth and energy consumption shock, over the period 1990-2020, in Iran. We employ a Bayesian vector autoregressive (BVAR) with new prior functions, which will give results more acceptable consequences than the classical methods to study these relationships. This study estimates the relationship between energy consumption shocks and economic growth within a multivariate BVAR framework by including gross capital formation, Labor and carbon dioxide emission. The multivariate impulse responses to shocks in all the variables are obtained. The results show that, there is a positive impact of energy consumption shocks on economic growth in Iran and this means that energy consumption is crucial for economic growth. Also, the responses of economic growth to one-unit shock of gross capital formation and labor force are positive and the responses of economic growth to the one-unit shock of carbon dioxide emission is are negative.

Keywords: Bayesian VAR; economic growth; energy consumption; Iran

1 INTRODUCTION

Theoretically, there is a relationship between energy consumption and economic growth. This relationship can affect the people health status and the environment in the countries with high-energy consumption. In these countries, industry is responsible for 22% of global greenhouse gas emissions, results from burning fossil fuels for energy. Economists have considered the effect of energy consumption on economic growth in recent years. Since energy, consumption affects various aspects of economic activities, so it has an impact on a country's efforts to achieve long-term economic growth. The two energy crises (1974 & 1981) have raised much empirical analysis as to relationship between energy consumption and economic growth [17, 10, 24, 32, 14, 19, 13, 18].

Ayres and Nair (1984) study, by biophysical growth model show that energy is the incite of growth via labor and capital energy consumption. Ref. [33] suggested the relationship between energy and output that influenced by substitution between energy and other production inputs, variation in technology, energy factor combination, products combination and also variation in other inputs combination. Ref. [28] investigates the dynamic relationship between energy consumption and economic growth in nine South and Southeast Asian countries using a panel data framework. The IRFs show that the shocks of energy consumption on economic growth, it takes a long time to achieve long-term balance. Ref. [12] show that both the non-renewable and the renewable energy consumption are positively increase economic growth for selected country of OECD. Ref. [25] analyze the effects of Energy security, electricity, population on economic growth in the case study of developing South Asian resource-rich economy. Basis on the results, a 1% increase in population increases electricity consumption by 4.16%. Ref. [6] and [31] assessed the nexus between renewable energy consumption and Economic growth in 26 European countries and China. Based on [6], a 1% increase in renewable energy consumption will increase economic growth by 0.054% in these countries. Ref. [31] showed that renewable energy, non-renewable energy, capital and labor have positive effect on economic growth.

Energy is one of the essential production factors that plays an important role in the economic, sociocultural, and political progress of countries. The development and implementation of energy policies, which can balance the energy supply and demand, are becoming a strategic issue, especially for energy-dependent countries [37]. The developing countries struggle to obtain energy sources reliable in the end to complete their economic development process, and the developed countries struggle to get them to keep their present prosperity levels [38].

This study analysis the effects of energy consumption shocks on economic growth using BVAR model in Iran. According to our finding, there is not any similar research paper in this topic. In this study, we specify the investigation in Iran, a country with high-energy resources and highly energy intensive. The main purpose of this study is to reveal any nexus between energy consumption shocks and economic growth in Iran using Bayesian Vector Autoregressive model. The paper is organized as follows: Section 2 reviews material and methodology; Section 3 and 4 presents the results and discussion, respectively, and section 5 presents the conclusion.

2 MATERIALS AND METHODOLOGY

Vector Autoregressive (VAR) models have a fundamental problem. This problem, called parameter abundance, in cases where observations are low (Iran), model forecasts inappropriate. Therefore, should look for a way to reduce the number of model parameters and constrain the models. Bayesian methods as a way of overcoming this problem have become increasingly used with researchers [16].

Bayesian models have three components. Prior density function, the posterior density function, and likelihood function. Therefore, it is important to select the appropriate

prior function for the Bayesian models. Various prior functions have been used in Bayesian autoregressive models, the famous of which is Minnesota prior function that first introduced by [9]. The Bayesian methods are sensitive to the type of prior function used, in this paper four different prior functions are used to estimate the model and finally, using the RMSE index, selected the best prior function for calculate impulse response functions.

2.1 Bayesian Vector Autoregressive Model

The Bayesian approach is a recommended method for energy consumption and Energy resource melioration and CO_2 emissions in different fields [5]. Ref. [21] originally proposed a Bayesian approach to VAR estimation. The Bayesian model can be introduced by:

$$y_t = \beta x_t + \varepsilon_t \tag{1}$$

where $X_t = (I_n \otimes W_{t-1})$ is $n \times nk$ matrix, $W_{t-1} = (y'_{t-1}, y'_{t-2}, ..., y'_{t-p}, z'_t)$ is $k \times 1$, and $\beta = vec(b_1, b_2, ..., b_p, D)$ is $nk \times 1$ rank. The passive parameters are B and Σ.

Estimation of the parameters is entirely direct. By mixing the likelihood function of the parameters below:

$$L(y \mid \beta, \boldsymbol{\Sigma})\alpha \mid \boldsymbol{\Sigma} \mid^{-\frac{T}{2}} \exp\left\{-\frac{1}{2}\boldsymbol{\Sigma}_t (y_t - x_t\beta)' \boldsymbol{\Sigma}^{-1}(y_t - x_t\beta)\right\} \tag{2}$$

and the parameters, $p(B, \Sigma)$, obtained as follows [7].

$$p(\beta, \Sigma \mid y) = \frac{p(\beta, \Sigma)L(y \mid \beta, \Sigma)}{p(y)} \tag{3}$$

2.2 Priors

In this study, four priors' basis is used [11, 8, 30]:

1) The Litterman/Minnesota prior
2) The Normal-Wishart prior
3) The Sims-Zha normal-Wishart prior.
4) The Sims-Zha normal-flat.

2.3 Empirical Model and Data

Five variables including carbon dioxide emissions (*kt*) (CO_2), gross domestic product (US$) (GDP), capital formation constant (US$) (*K*), labor force (*L*) and energy consumption (millions tons) (EC) have been considered for the case study of Iran in this study. The data is collected over the period 1990-2020 from World Bank statistical resources and log form are consistency (*LCO2*, *LEC*, *LK*, *LL* and *LGDP*).

The regression based on the following function:

$$LGDP_t = f(LL_t, LK_t, LEC_t, LCO2_t) \tag{4}$$

The Bayesian VAR model used in this study, based on the study by [29], [12] and [28] and is given as:

$$GDP_t K_t L_t EC_t CO2_t = z'_t c + \\ + \sum_{j=1}^{2} (GDP_{t-j} K_{t-j} L_{t-j} EC_{t-j} CO2_{t-j}) A_j + \\ + (\varepsilon_t^{GDP} \varepsilon_t^{K} \varepsilon_t^{L} \varepsilon_t^{EC} \varepsilon_t^{CO2}) \tag{5}$$

For $j = 1,\ldots, N$ and $t = 1,\ldots, T$.

Based on the Fig. 1, energy consumption in Iran has had a relatively increase trend, increasing by 176% over the period from 1990 to 2018. Between 1995 and 1996 and 1999 to 2000, energy consumption declined slightly and then increased.

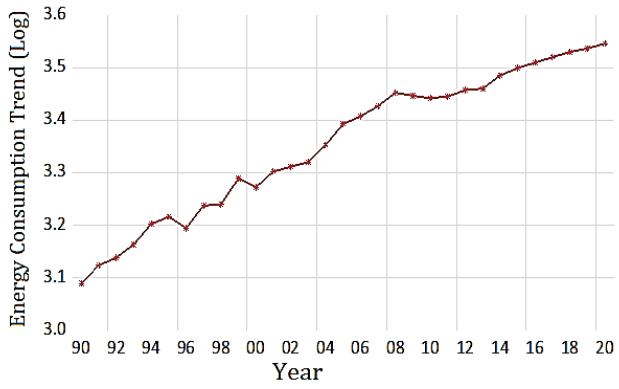

Figure 1 Energy consumption trend (Logarithmic)

According to Fig. 2, GDP growth in Iran has been relatively fluctuating, increasing and declining over time. The highest increase was for the period 2001 to 2008, which increased by 43% and the largest decrease was for the period 2011 to 2013, which decreased by 7.6%. During the total period, GDP in Iran increased by 135 percent.

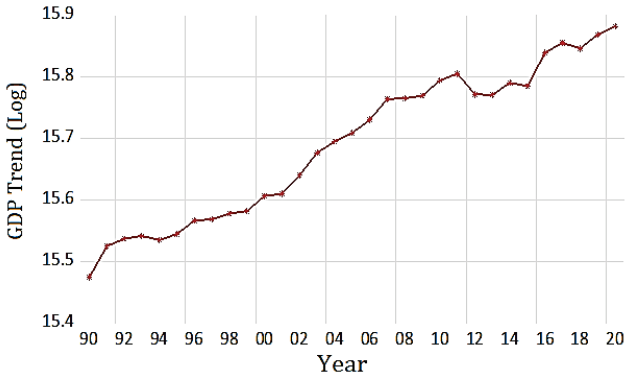

Figure 2 Gross domestic product (GDP) trend (Logarithmic)

3 RESULTS

Stationary test is ADF unit root test. Based on the Tab. 1, all variables are non-stationary at level but become stationary after first difference. Basis on Tab. 2 and results of

tests, two period lagged values of the variables used in the analysis.

Table 1 Result of ADF unit-root test

Variables	Level	1st Difference
LCO_2	–1.35	–5.38*
LEC	–1.68	–6.96*
LGDP	–1.06	–5.27*
LK	–0.82	–3.97*
LL	–1.40	–2.66**

Note: * and ** denote significance at 1% and 5% level respectively

Table 2 Determination of optimum lag length for VAR model

Lag	*LR*	*AIC*	*SBC*	*FPE*	*HQ*
0	-	–19.40	–19.16	2.56e–15	–19.33
1	167.20*	–25.84	–24.39	4.28e–18	–25.42
2	35.30	–26.27*	–25.61*	3.54e–18*	–25.51*
3	25.56	–26.11	–23.03	3.93e–18	–24.46

Tab. 3 shows the results that is derived from the co-integration tests. Both tests reject the null hypothesis of zero co-integrating vectors. In the other hand; based on the co-integration test, the hypothesis that there is one co-integrating vector cannot be rejected, so there is no support for both variables in the system being stationary. Based solely on the evidence in Tab. 3, we would conclude that there exists a co-integrating relationship.

Table 3 Results from Co-Integration Test

Null hypothesis	J_{trace}	*p*-value	J_{max}	*p*-value
$r = 0$	84.73	0.002	30.57	0.017
$r = 1$	54.16	0.011	26.16	0.045
$r = 2$	27.99	0.079	16.44	0.200
$r = 3$	11.55	0.179	8.64	0.316

For comparing, the performance of different models and their goodness of fit in Bayesian econometric literature it is needed to evaluate their prediction accuracy. The predictions of each models that is mentioned above are presented in Tab. 4.

Table 4 Prediction one period ahead of variables

Prior function	$LCO2_{t+1}$	LEC_{t+1}	$LGDP_{t+1}$	LK_{t+1}	LL_{t+1}
Minnesota	5.61	3.32	15.66	15.17	7.30
Normal-Wishart	5.70	3.43	15.71	15.22	7.35
Sims-Zha (Normal-Wishart)	5.68	3.28	15.69	15.18	7.39
Sims-Zha (Normal-flat)	4.59	3.37	15.65	15.13	7.36
Real quantity	5.62	3.34	15.67	15.16	7.31

Some indexes such as *RMSE* are used to check the accuracy of prediction of different prior function. This index can be defined as follows:

$$RMSE = \sqrt{\frac{\sum_{\tau=\tau_0}^{T-h}\left[y_{i,\tau+h}^{0} - E(y_{i,\tau+h} \mid Data_{\tau})\right]^2}{T-h-\tau_0+1}} \tag{6}$$

With considering τ_0 = 1990 and different forecast horizons from $h = 1$ to $h = 2$, we compared the predictions of each of the above prior function. Tab. 5 shows the RMSE index for different models and forecast horizons. The results show that the BVAR model using Minnesota prior function provides more accurate predictions than other priors do. Therefore, analyze the effect of energy consumption shocks on economic growth in Iran, using BVAR method with Minnesota prior function.

Table 5 RMSE Index Prediction

Prior function	One period ahead					Two period ahead				
	LCO2	*LEC*	*LGDP*	*LK*	*LL*	*LCO2*	*LEC*	*LGDP*	*LK*	*LL*
Minnesota	0.02	0.01	0.02	0.07	0.02	0.01	0.01	0.02	0.06	0.01
Normal-Wishart	0.03	0.03	0.03	0.08	0.02	0.02	0.02	0.02	0.06	0.02
Sims-Zha (Normal-Wishart)	0.02	0.03	0.02	0.11	0.02	0.02	0.01	0.04	0.09	0.02
Sims-Zha (Normal-flat)	0.02	0.03	0.02	0.09	0.05	0.01	0.02	0.04	0.07	0.03

3.1 Impulse Response Function

In this paper, such as [10] the reduced form VAR model and to identify the shocks the current Cholesky decomposition is used. In the VAR models to investigation the effect of a shock in a specific variable on other variables the impulse response functions are used. In addition, impulse response functions obtained with Minnesota prior function is analyzed. Fig. 3 (left hand and above) shows that, the carbon dioxide emission shock (*LCO2*) initially has a negative effect on economic growth that result according to those of [26, 2], which have the most negative impact in the third period and decrease after the third period in a stationary way. In addition, until second period, the effect of the energy consumption shock (*LEC*) (right hand and above) has been increasing and after the second period the effect of this shock has reduce and converged to its mean value, that result consenting to those of [6, 31, 15]. Gross fixed capital shock (*LK*) (left hand and low) has a positive effect on economic growth until the second period that result consenting to those of [31], and after the second period the effect of the shock has been reduced and fixed at its average value after 5 periods. The workforce (*LL*) (right hand and low) has an extra impact on economic growth from the beginning to the fifth period, this result according to those of [31], reaching its peak in 5 periods and then converging to its stable value.

3.2 Variance Decomposition

After entering a specific shock to the system, all variables are trend different from the predictions follow-up system. If we call the gap a prediction error, the analysis of the variance is called the percentage of the variance causes to the shock. In this study, we consider the forecasting error variance decomposition of the variable of economic growth. According to the estimated model based on Minnesota prior function, the results of the analysis of variance decomposition for ten periods are given in the Tab. 6.

Based on the Tab. 6, *S.E* columns shows the prediction error of economic growth that illustrated by depended and independed variables. During the total period, the prediction error is explained by the economic growth variable. The prediction error of the other variables in the model is increased during the period, so that in the second period the labor force (*LL*) shock explains 4.68% of the prediction error of economic growth, which is the highest, and in the other hand, the least explain (0.35%) is related to gross capital formation (*LK*). As the results in Tab. 6 show, in the following periods, the explanatory of prediction error of economic growth is increased by energy consumption, gross capital formation, CO_2 emission and labor force, which in the tenth period, 40.14% prediction error explain by economic growth and energy consumption, gross capital formation, CO_2 emission and labor force explain the prediction error of economic growth variable 1.02%, 0.19%, 18.72% and 39.90%, respectively, which the greatest and least effect is belong to labor force and gross capital formation shocks, respectively.

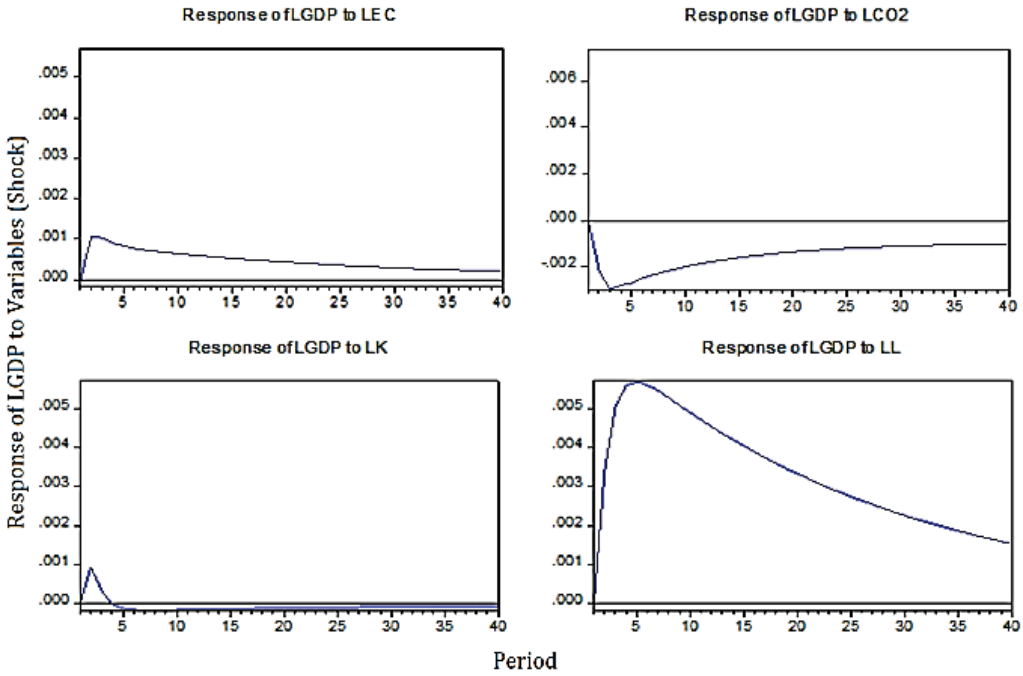

Figure 3 Impulse Response Function of Minnesota prior function

Table 6 Variance decomposition of Minnesota prior function

Period	*S.E*	*LGDP*	*LCO2*	*LEC*	*LK*	*LL*
1	0.014	100.00	0.00	0.00	0.00	0.00
2	0.015	91.35	3.14	0.44	0.35	4.68
3	0.016	78.50	7.58	0.75	0.341	12.80
4	0.018	67.63	10.93	0.88	0.29	20.25
5	0.019	59.43	13.33	0.95	0.26	26.01
6	0.020	53.35	15.06	0.98	0.23	30.35
7	0.021	48.77	16.34	1.00	0.22	33.65
8	0.022	45.22	17.32	1.01	0.20	36.22
9	0.023	42.41	18.10	1.02	0.19	38.25
10	0.024	40.14	18.72	1.02	0.19	39.90

Note: *S.E*: Prediction error variance of economic growth can be explained by exogenous shocks to the other variables; *LGDP*: Logarithm of Gross Domestic Product; *LCO2*: Logarithm of CO_2 emission; *LEC*: Logarithm of Energy Consumption; *LK*: Logarithm of Capital; *LL*: Logarithm of Labor.

4 DISCUSSION

The relationship between energy consumption and economic growth, especially after the first oil crisis in 1973 that increased oil prices, is one of the most important topics to study in the global economy context. The results of various studies in this field are not the same. The issue of energy in relation to the Iranian economy is important. Because Iranian economy is following the steps of realizing the price of energy carriers, and the question, which constantly raised is how the economic growth process will be affected by increasing the price of energy carriers and possible reduction of their consumption. Answering this question requires knowledge of the relationship between energy consumption and economic growth in the country and its dimensions. The main purpose of this study is to investigate the relationship between energy consumption and economic growth in Iran using BVAR model based on the objectives of the 20-year vision document of Iran. Capital and labor, are among the most important factors affecting economic growth that are considered in growth functions. In the new growth theories, the energy factor has also entered the model. Ref. [33] basis on ecological economists express that in biological models of growth, energy is the only and most important factor for growth, and since every production process needs energy, energy is always a factor in the production process. It is clear that the existence of energy source is a very important factor in the economic growth in Iran, because the effect of the energy consumption shock increase economic growth. Therefore, the result of this research confirms the importance of energy in economic growth in Iran, that result consenting to those of [6, 31, 15]. The results in this research have important implications for energy policy making in the Iran: given the high subsidies for energy, there is relatively more

scope for more intensive energy conservation measures without severe impacts on economic growth. Indeed, it seems unlikely that the elimination of energy price distortions restrains the economic growth. However, subsidy reform should be embedded in a reform program that create broad support and yield wide-spreading benefits.

5 CONCLUSION

The energy economics literature lacks a consensus on what are the short and long run linkages along with the Granger causality direction between economic growth and energy consumption. This paper assesses The Impact of Energy Consumption Shocks on Economic Growth: Using BVAR Approach for 1990-2020 in Iran. In so doing, we control the relevant variables such as CO_2 emissions, labor force, and capital, and use BVAR modeling approach. Empirically, we tested the validity of our growth model in the time series dataset of Iran during the period of 1990 to 2020. For this purpose, we run the time series unit root tests as well as the Bayesian vector autoregressive (BVAR) estimations. This study can be the first paper that analyses the effects of the energy consumption shocks on economic growth in Iran using BVAR approach. This study evaluates the relationship between energy consumption shocks and economic growth within a multivariate BVAR framework by including gross capital formation, Labor and carbon dioxide emission (CO_2). The multivariate IF's are indicate by unit shocks to all the variables. (i.e. *LGDP*, *LEC*, *LK*, *LCO2* and *LL*). We found the positive impact of energy consumption shocks on the economic growth in Iran and this means that energy sources are crucial for the economic growth. The responses of economic growth to a one-unit shock of gross capital formation (*LK*) and labor force (*LL*) are positive and carbon dioxide emission (*LCO2*) shock on economic growth is negative.

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Authors' contacts:

Ezatollah Abbasian, Associate Professor in Economics
(Corresponding author)
Department of Public Administration,
Faculty of Management,
University of Tehran,
Tehran, Iran
E-mail: e.abbasian@ut.ac.ir

Salaheddin Manochehri, PhD Candidate in Economics
Faculty of Economics and Social Sciences,
Department of Economics,
Bu-Ali Sina University,
Hamedan, Iran
E-mail: s.manochehri@eco.basu.ac.ir

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Analysis of the Mechanical Behaviour for the External Fixation Device under the Impact of Torque

Nedim Pervan*, Adis J. Muminović, Elmedin Mešić, Enis Muratović, Muamer Delić

Abstract: In this research, an analysis of the mechanical behaviour for the Orthofix external fixation device under the impact of torque was performed. Research considers application of the Orthofix device on the tibia bone for the case of unstable fracture. 3D (Three Dimensional) model of the Orthofix device was created in the CATIA (Computer Aided Three-Dimensional Interactive Application) software, based on the real device construction. Structural analysis was used to monitor and analyse the stress magnitudes on the specific areas of the fixation device and fracture. With usage of the interfragmentary displacement data for the bone fragments, degrees of stiffness are introduced for the fracture and fixation device. Obtained results are used to specify the mechanical behaviour of the Orthofix fixation device.

Keywords: external fixation device; interfragmentary displacements; mechanical behaviour; principal stresses; stiffness analysis

1 INTRODUCTION

With ever increasing number of traffic accidents which involve motorcycle drivers, especially in recent years, external fixation devices are essential due to open fractures that may occure. External fixation device is a construction used for the purposes of the bone surgery and treatment of various types of trauma. These devices are used to fixate the bone fragments with application of pins, which are fastened into the bone fragments on the one side, while their other side is connected with the construction i.e. frame of the fixation device [1].

Design solutions for the fixation devices were developed along with the expansion of technology and medicine. For an example, simple design solutions accomplish fracture stability requirements, modular designs enables simple and fast utilization and circular devices with thin pins provide control of the small bone fragments. External fixation devices are often used with the adjustable couplings which enable dinamization in order of providing specific pressure on the bone segments [2].

Rapid evolution of computer sciences and software development has led to various softwares for 3D modeling and numerical analysis. In recent period, implementation of these softwares is inevitable for structural analysis of the fixation devices. With the 3D model and numerical analysis, a lot of data can be obtained, such as values of von Mises stress, displacement for the points of interest, as well as stress distributions and displacements of the fixation device itself [3-9].

The goal of this research is to examine the mechanical behaviour of the Orthofix external fixation system applied to the tibia bone under the impact of torque, for the case of unstable fracture.

2 DEVELOPMENT OF CAD MODEL

Orthofix fixation device represents one of the modern solutions developed for the needs of external fixation. Device is made of the austenite stainless steel (AISI 304 according to EN 10088 i.e. EN 58E) and anodized alloy of the aluminium (T6-7075 according to EN 573-3 i.e. AlZn5MgCu), coated with the layer of Polytetrafluoroethylene (PTFE). Fig. 1. shows the appearance of the Orthofix fixation device with distinguished aluminium and steel parts, in black and grey color, respectively.

Figure 1 Orthofix fixation device

Table 1 Mechanical properties of the Orthofix fixation device components

Component name	Standard denotation (AISI)	Standard denotation (EN)	Modulus of elasticity E (GPa)	Poisson's ratio υ	Denstiy ρ (kg/m^3)	Yield strength σ_v (MPa)
Truss	7075-T6	AlZn5MgCu	71.7	0.33	2810	460
Couplings	7075-T6	AlZn5MgCu	71.7	0.33	2810	460
Spherical joints	AISI 304	EN 58E	193	0.29	7900	205
Coupling fasteners	AISI 304	EN 58E	193	0.29	7900	205
Half-pins	1.4441	X$_2$CrNiMo18	196.4	0.3	8000	800

Aluminium is a non-magnetic and corrosion resistant in various environments, and it is also less expensive when compared to other metals. Black aluminium color for the device components is acquired with the anodizing surface treatment. Austenite stainless steel is attributed with great resilliance to intercrystalline corrosion, while it has reduced

yield strength, due to smaller proportion of carbon and a different structure. Mechanical properties of the Orthofix fixation device components are shown in Tab. 1 [10].

Development of the CAD model for the Orthofix device, based on properties of the physical model, is performed in the CATIA software. Device components are formed with the parametrization method, which enables connectivity between specific dimensions and reduces the time needed for corrections. Each component is created in the Part Design module, while complete fixation system is created by assembling these components in the Assembly Design module.

Apart from the Orthofix CAD model, tibia bone model is also created. Tibia is modeled as an ortotropic material with specifications according to Tab. 2 [11].

Table 2 Mechanical properties of the tibia bone

Property	Value
Longitudinal modulus of elasticity	22900 MPa
Tangential modulus of elasticity	10500 MPa
Normal modulus of elasticity	14200 MPa
Poisson's ratio for XY plane	0.29
Poisson's ratio for XZ plane	0.19
Poisson's ratio for YZ plane	0.31
Shear modulus for XY plane	6480 MPa
Shear modulus for XZ plane	6000 MPa
Shear modulus for YZ plane	3700 MPa
Material density	1850 kg/m^3

3 DEVELOPMENT OF FEM MODEL

Development of the FEM (Finite Element Method) model is performed in the CATIA software. One of the greatest advantages of the mentioned software is reflected in associativity, compared with other analysis softwares. This means that any change of CAD model parameters will be automatically updated in the FEM model.

FEM model development starts with discretization and selection of the finite element type. Discretization must be performed with the elements which are sufficiently small, so that usable results may be obtained. Also, the size of finite elements must be in accordance with computer performance capability [12, 13]. Components of the Orthofix fixation device are modeled with the linear and parabolic tetrahedron finite elements. Linear tetrahedrons are used for couplings, spherical joints and fasteners, while parabolic tetrahedrons are used for truss, tibia, and half-pins.

Once discretization is complete, connection properties for the Orthofix device are defined. Interaction between half-pins and bone models is established via fastened connection property (Fig. 2a). Fastened connection is a feature defined over the boundaries of the selected parts, where these parts are than handeled as one body. Second type of connection used to establish Orthofix system is contact connection property (Fig. 2b). With this connection property, penetration of bodies is restricted i.e. bodies can still move but only up to point where they reach strictly defined clearence.

Once virtual parts are applied, it is necessary to define torque. When analysing the basic strains, torque is the case where any cross-section of a rod is influenced with the external forces. This effect is reduced to a moment M_t, corresponding to a vector parallel to the longitudinal axis of the rod. This moment is called torque moment [14].

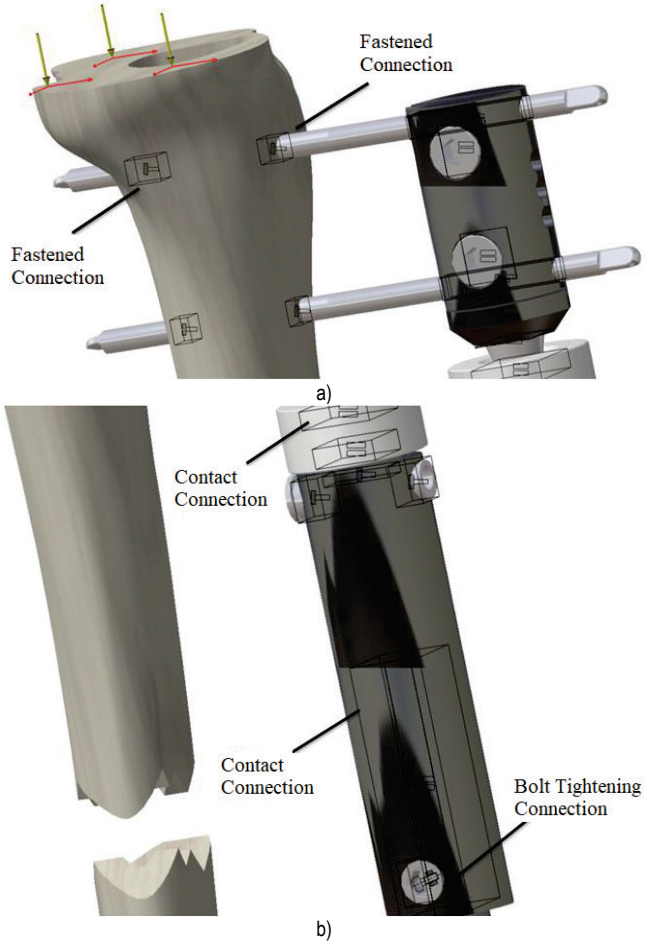

Figure 2 Connection properties for the Orthofix model: a) fastened connection, b) contact connection

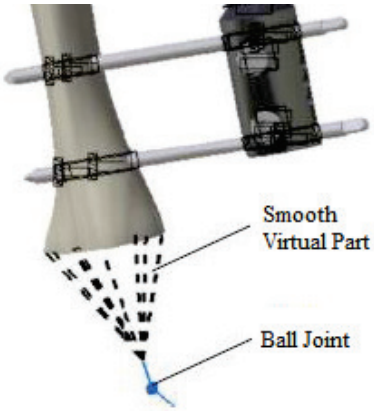

Figure 3 Fixation device model with defined virtual parts

Structural analysis of the fixation device is performed by clamping the bottom of the tibia bone model i.e. restricting all degrees of freedom. The torque moment is applied on the top of the bone model along with cylindrical joint restriction which enables one rotation about the axis of the bone model (Fig. 4).

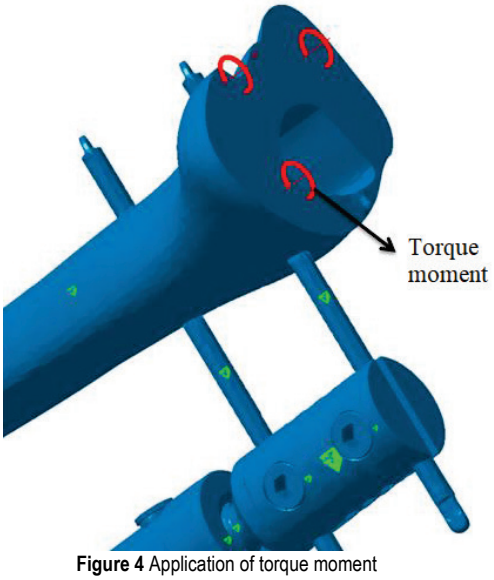

Figure 4 Application of torque moment

With the structural analysis, values of the principal stresses and von Mises stress were monitored, for the applied torque moment between the values 0 – 15 Nm. Von Mises stress is often used in the solid body mechanics and it is defined via Eq. (1) [15]:

$$\sigma_e = \sigma_{vm} = \sqrt{3J_2} = \\ = \sqrt{\frac{1}{2}\left[(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2\right]}. \quad (1)$$

Beside stress values, angular rotation for the appropriate bone model point was also monitored. Based on these values, Orthofix device stiffness is defined with Eq. (2) [16]:

$$C_u = \frac{M_u}{\theta}, \quad (2)$$

whereas: M_u – torque moment (Nm), θ – torque angle at the load application zone (rad).

For the purposes of stiffness definement, translational displacement for the proximal segment end point, at the load zone, is calculated (Tab. 3). These values are then translated into angular rotation via Eq. (3) [16]:

$$\tan\theta = \frac{p}{l'}, \quad (3)$$

whereas: θ – torque angle, p – translational displacement of the considered point, l – distance between axis of the segments and considered point (Fig. 5).

Without any doubt, the stiffness of the fixation device construction is important, but it does not provide direct insight about the fracture movement. More precise information may be obtained by investigating real relative movements of the bone ends under simulated load conditions.

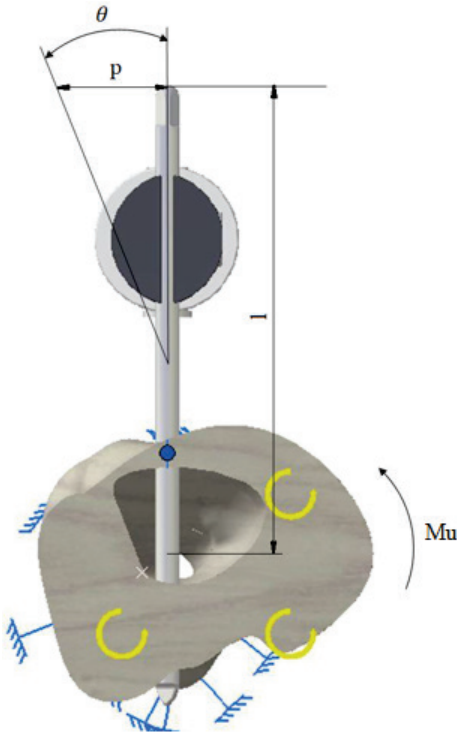

Figure 5 Displacement of the segmetns undert the impact of torque

In order to define fracture stiffness, a displacement is determined for the x, y and z directions for the pair of the adjecent points on the end planes of the proximal and distal segments at the fracture zone. For these points, resulting displacement vector (R), has the maximum value.

Relative displacements ($r_{D(x)}$, $r_{D(y)}$, $r_{D(z)}$) of the considered points in the x, y and z direction are expressed by Eq. (4) [17]:

$$\begin{aligned} r_{D(x)} &= D_{p(x)} - D_{d(x)} \\ r_{D(y)} &= D_{p(y)} - D_{d(y)}, \\ r_{D(z)} &= D_{p(z)} - D_{d(z)} \end{aligned} \quad (4)$$

Fracture stiffness is defined as ratio of the applied load and resultant relative displacement for the considered pair of points, as shown with Eq. (5) [16]:

$$C_{pu} = \frac{M_u}{R} = \frac{M_u}{\sqrt{(r_{D(x)})^2+(r_{D(y)})^2+(r_{D(z)})^2}}. \quad (5)$$

4 RESULTS

Fig. 6. shows the displacement vectors of the points under the maximum torque load. Direction, course and the intensity of the vectors are clearly noticeable. Components of the displacement vector can also be determined (Tab. 3).

In order to analyse the stiffness of the construction under the impact of torque, displacement in the y direction, of the central point at the proximal segment load zone, was observed. With usage of Eq. (4), relative displacements for

the end points of the proximal and distal segments are determined.

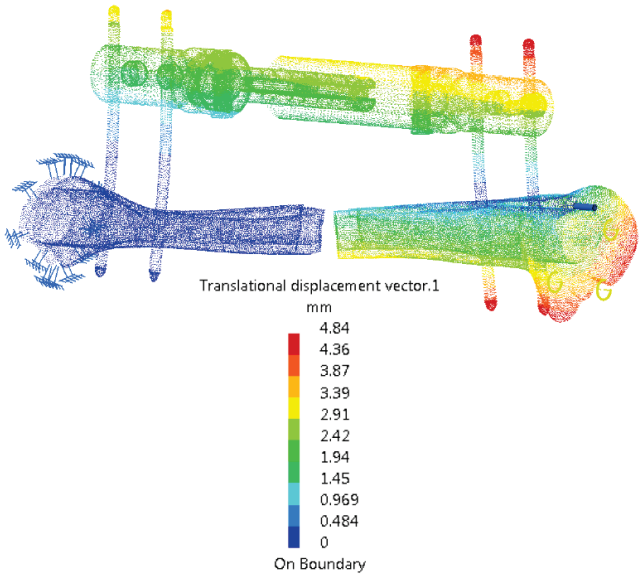

Figure 6 Displacement vectors under the impact of maximum torque

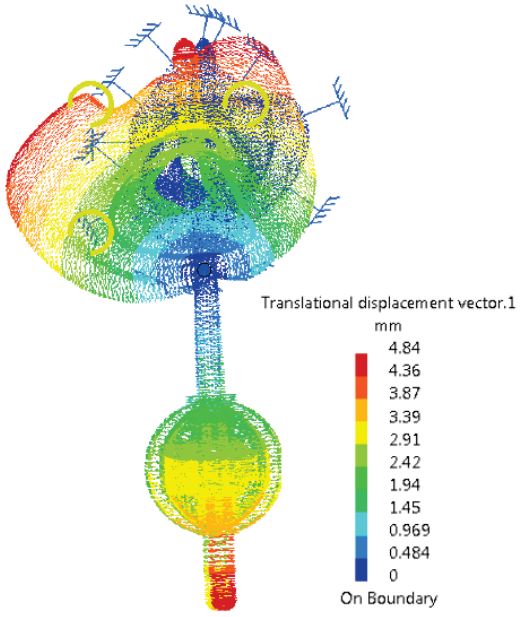

Figure 7 Displacement vectors in the load zone, under the impact of maximum torque

Angular rotation and displacement of the points for the bone model in the load zone, under the impact of the maximum torque, are shown in Fig. 7.

Values of the displacements for the maximum torque moment of 15 Nm, are presented in Tab.3.

For the maximum torque, greatest displacement of the fracture area amounts 4.84 mm and it is located at the top of the bone model i.e. brim of the upper segment. Greatest displacement for the fixation construction is located at the top and at the end of the half-pins, and it amounts 4.84 mm.

Stress values are variable and dependant of the construction shape. Most critical and most loaded zones of the construction are half-pins and contact areas between half-pins and couplings (Fig. 8).

Table 3 Displacement and stiffness values

Displacement of the proximal segment (mm)	Load zone	x	0.031
		y	1.49
		z	0
	Fracture zone	$D_{p(x)}$	0.0021
		$D_{p(y)}$	–0.26
		$D_{p(z)}$	3.24
Displacement of the distal segment (mm)	Fracture zone	$D_{d(x)}$	0
		$D_{d(y)}$	0.027
		$D_{d(z)}$	0
Torque angle (rad)		θ	0.083
Fracture stiffness (Nm/mm)		C_{pu}	3.875
Construction stiffness (Nm/rad)		C_u	180.72

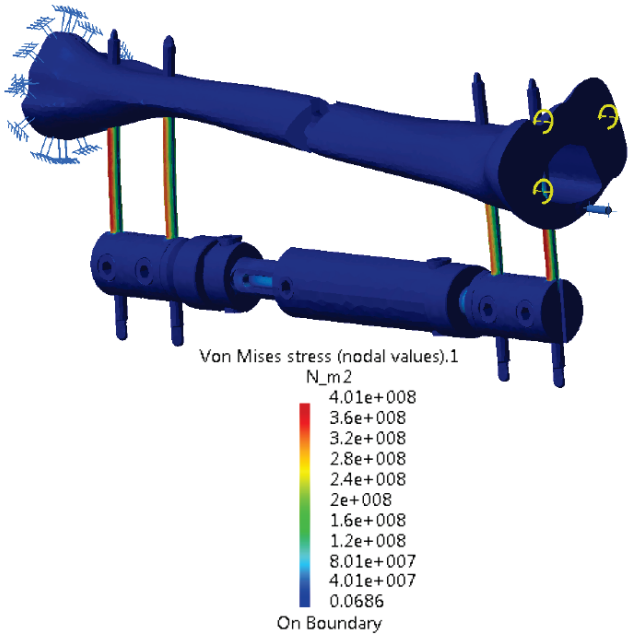

Figure 8 Distribution of the von Mises stress

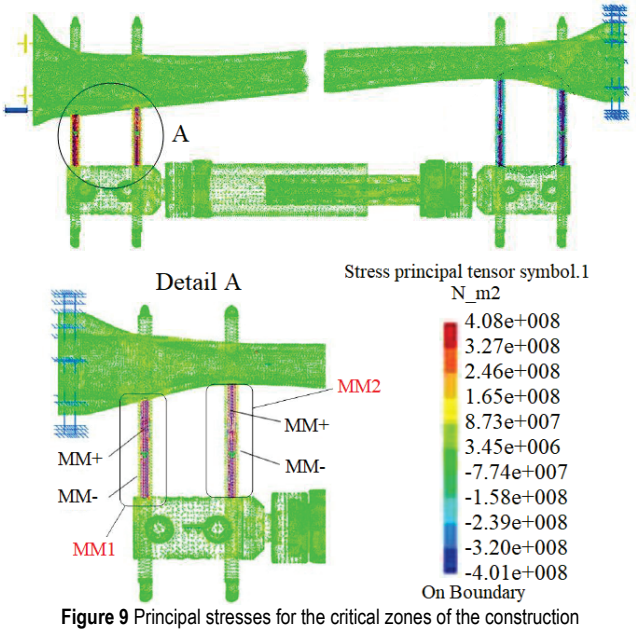

Figure 9 Principal stresses for the critical zones of the construction

These critical zones are used to collect data about intensity and direction of principal stresses (Fig. 9). Result of the 2 observed zones (MM1 & MM2) are shown in Tab. 4.

Table 4 Stress values for the maximum torque

Measuring point			MM1	MM2
Principal stresses for the fixation device critical zones (MPa)	MM+	σ_1	269.21	118
		σ_2	–4.25	4.17
		σ_3	–6.90	–11.50
	MM–	σ_1	119.36	13.30
		σ_2	–0.63	–0.45
		σ_3	–3.66	–11.80
Von Mises stress for the fixation device critical cross-section (MPa)	MM+	σ_{vm}	274.79	122.40
	MM–	σ_{vm}	121.53	21.76

5 CONCLUSION

Mechanical behaviour of the external fixation device have an enormous impact on the fracture treatment, by influencing the biomechanical fracture environment. The main task of the external fixation device is to stabilise the fracture during the treatement. In order of accomplishing this task without any mistakes and defects, it is necessary to adjust the size, shape and the relative position for each of the fixation device component. This adjustements need to correspont to the clinical needs i.e. information about the constructive parameters and loads are mandatory for the construction process.

In this research, an analysis of the mechanical behaviour for the Orthofix fixation device under the impact of torque was performed. With usage of the CATIA software, 3D model of the fixation device was formed. This model is fundamental for further FEM analysis, used for observing mechanical behaviour of the fixation device, which involve fracture movements, construction behavior under load and stiffness definition.

Structural analysis showed that maximum displacement of the fracture is located at the top of the tibia bone model with value of 4.84 mm, while maximum fixation construction displacement also amounts 4.84 mm, and it is located at the top and at the bottom of the half-pins. Displacements for the distal bone segment have small values, due to clamp restrain.

Using the displacement values for the fracture zone, obtained with analysis, fracture stiffness which amounts 3.875 Nm/mm is defined. Similarly, using the values of the angular rotation of the bone model, construction stiffness which amounts 180.72 Nm/rad is defined. Both of the defined stiffnesses satisfy the permitted limits for these types of constructions.

Values and directions of the principal stresses were observed for the 2 critical zones under the impact of maximum torque load. These zones are half-pins and area of the connection of the half-pins and couplings. Greatest stress is located on the critical zone 1 (MM1) and amounts 274.79 MPa, which satisfies the permitted stress value for the half-pin material.

By analysing the intensities and directions of the principal stresses it is noticeable that the truss is conducted to the effects of the uneven stresses of tension and pressure in two perpendicular directions, due to length of threaded connection and the bone asymmetry.

Based on the presented results and their analysis, it can be concluded that Orthofix device shows good mechanical behaviour under the impact of torque. These behaviour can be further improved by using new materials for fixation device components or with redesign process of the device.

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Authors' contacts:

Nedim Pervan, PhD, Associate Professor
(Corresponding author)
University of Sarajevo, Faculty of Mechanical Engineering,
Vilsonovo šetalište 9, 71000 Sarajevo, Bosnia and Herzegovina
+38733729800, pervan@mef.unsa.ba

Adis J. Muminović, PhD, Associate Professor
University of Sarajevo, Faculty of Mechanical Engineering,
Vilsonovo šetalište 9, 71000 Sarajevo, Bosnia and Herzegovina
+38733729800, adis.muminovic@mef.unsa.ba

Elmedin Mešić, PhD, Full Professor
University of Sarajevo, Faculty of Mechanical Engineering,
Vilsonovo šetalište 9, 71000 Sarajevo, Bosnia and Herzegovina
+38733729800, mesic@mef.unsa.ba

Enis Muratović, PhD Student, Teaching Assistant
University of Sarajevo, Faculty of Mechanical Engineering,
Vilsonovo šetalište 9, 71000 Sarajevo, Bosnia and Herzegovina
+38733729800, muratovic@mef.unsa.ba

Muamer Delić, PhD, Assistant Professor
University of Sarajevo, Faculty of Mechanical Engineering,
Vilsonovo šetalište 9, 71000 Sarajevo, Bosnia and Herzegovina
+38733729800, delic@mef.unsa.ba

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Conceptual Model of Managing Resilience in Supply Chain

Matija Kovačić*, Maja Mutavdžija, Krešimir Buntak

Abstract: The supply chain is the basis for the functioning of today's society because it ensures the timely supply of all the resources needed to produce products or provide services offered in the market. Due to changes in the environments in which the supply chain exists, new risks arise that could jeopardize its functioning. Interruption in the normal functioning of the chain may result in the risk of inability to meet the requirements of stakeholders. Given this, the aim of this paper is to define a conceptual model of supply chain resilience management. The paper is based on the conducted secondary research and analysis of the achievements of other researchers in this field. The model described in this paper is based on the principles of the quality management system and provides a systematic approach to the analysis of supply chain threats, defining measures to reduce the threat, and testing and improving the established system.

Keywords: quality management; resilience; supply chain; supply chain risk management

1 INTRODUCTION

The supply chain is a set of stakeholders that enable the movement of raw materials, production, storage and delivery of products and services from the place of production to the place of consumption and disposal of used products in a harmless way for the environment. [1] In other words, a supply chain consists of several different organizations that are interconnected in a chain.

Despite the connectivity, each organization is a system unto itself and is different from other organizations. Changes in one organization may result in changes in other organizations. Changes can result in a crisis, i.e. a break in the normal functioning of the entire chain.

Each stakeholder in the supply chain functions within its own context. The stakeholder context in the chain is determined by the general environment, the industrial environment and the internal environment of the stakeholder [2]. The general environment of the stakeholder refers to economic trends, political environment, technological trends and social trends within the system in which the stakeholder exists. The industrial environment is determined by competition, customers and general trends within the industry of the organization. Finally, the internal environment is determined by organizational structure, culture, and resources. [3] Due to the different contexts in which each stakeholder exists, there are different risks that can jeopardize the business continuity of each stakeholder. An example of such a risk is the global crisis caused by the SARS CoV-2 virus pandemic that has led to reduced throughput in global supply chains. In addition to a pandemic, an economic crisis that can affect the economic system in which a stakeholder in the supply chain operates can also affect disruptions, wars and political instabilities can disrupt or affect a slowdown in the supply chain.

2 GENERAL SYSTEM THEORY AND SUPPLY CHAIN

General system theory can be used for the description of relations within the supply chain as it clarifies the interrelationship between system components. [4] In other words, the basic premise of general system theory emphasizes how each system consists of multiple subsystems and how each subsystem interacts with other subsystems. Changes in one of the subsystems may affect changes in other subsystems. If such settings are generalized to a supply chain that is a complex system by design, changes in one of the stakeholders involved in the chain may imply changes in other stakeholders [5].

On the other hand, following the general theory of the system, the performance of the entire system is determined by the performance of individual components within the system. The overall efficiency of the supply chain, i.e. the overall performance of the supply chain is determined by the partial performance of the stakeholders within the supply chain.

Since the stakeholders in the supply chain are in most cases interconnected in series, the total performance of the supply chain represents the product of the performance of each of the stakeholders involved in the chain.

One of the fundamental characteristics of serially connected elements relates to the creation of bottlenecks that can affect the slowing down of the flow of resources through the chain. Bottlenecks may be components in which the efficiency is known to be less than the efficiency of the other components. [6] In the end, they can result in increased costs, i.e. the risk of breaking the chain.

On the other hand, designing a supply chain using a parallel connection can also mean the risk of creating stocks or redundant activities. Such activities can also mean an increase in costs in the overall chain. However, in cases where stakeholders are involved in a parallel relationship and can deliver the same quality of service or service of the same quality (which is crucial to maintain the same level of quality of the final product), they can be included in a chain with half their capacity which will reduce costs and increase the reliability of the entire chain. This approach opens the possibility for organizations to direct part of their business to one supply chain, and the other part of their business to another part of the chain.

3 SUPPLY CHAIN RESISTANCE

Supply chain resilience can be defined as the ability of organizations involved in the supply chain to identify and respond promptly to a risk that may jeopardize the normal functioning of the chain or reduce its performance. [7] Several factors, which depends primarily on the needs of organizations in the chain, or the needs of customers and users for whom the supply chain was created can determine resistance of the supply chain. Due to the development of competitive advantage and the need to increase efficiency, i.e. reduce costs in the chain, organizations seek to implement various solutions in the supply chain that can make it vulnerable to risks. In other words, the elimination of certain activities such as controls, the development of mechanisms and procedures in the event of the risk of chain breakage, can result in the appearance of places in the chain that have reduced resistance. With the appearance of variability from the environment, there may be a risk that will affect the breaking of the chain or a decline in its performance, which will affect the functioning of organizations involved in the chain and society in general. In other words, the design of the supply chain according to the Lean principle brings with it advantages in terms of reducing costs and increasing the efficiency of the chain, but also increasing the risk associated with a decline in resilience.

If there is an interruption in the supply chain, the supply chain goes through several phases: the phase of initial impact, interruption of function, preparation for recovery, recovery and ultimately long-term consequences due to interruption in functioning. It should be emphasized that the downtime of the supply chain should be as short as possible as longer downtime can result in greater long-term consequences. [8] Two interruptions can be identified in the supply chain, sudden (Fig. 1) and gradual (Fig. 2). The fundamental difference relates to the time it takes for the supply chain to consolidate and continue to function, that is, the speed at which the flow or function of the chain is interrupted. Fig. 1 shows an example of a sudden break in chain functionality. The performance drops sharply after the appearance of variability in the chain and it starts to grow again with time and the measures are taken. The greater the time that the chain spent in the break, the greater the consequences, i.e. the costs that occur, and vice versa.

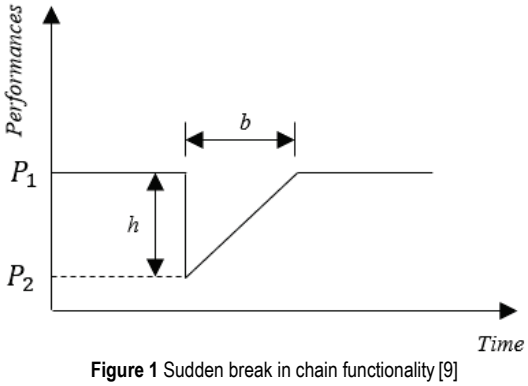

Figure 1 Sudden break in chain functionality [9]

Fig. 2 shows a situation in which variability in the chain occurs gradually and in parallel with this, there is a gradual decline in performance in the chain. The reason for the gradual decline may be the developed partial resistance of the chain, i.e. the lack of indicators that would record the decline and prevent its continuation.

When it comes to the place in the supply chain that is exposed to special risks associated with the rupture of the chain, or interruption of its functionality, in practice, most of the problems were recorded on the part of the supplier. Resource suppliers are the foundation of the normal functioning of the chain as they provide all the necessary resources that are necessary for the manufacturer to carry out the production process. Interruption in the functioning of the supplier may result in an interruption in the functioning of the manufacturer who cannot deliver the required quantity of products or services to the customer or user. Therefore, the interruption of supply leads to a lack of capacity, i.e. a lack of capacity of the supplier who is affected by some risk results in a decrease in capacity in the entire supply chain

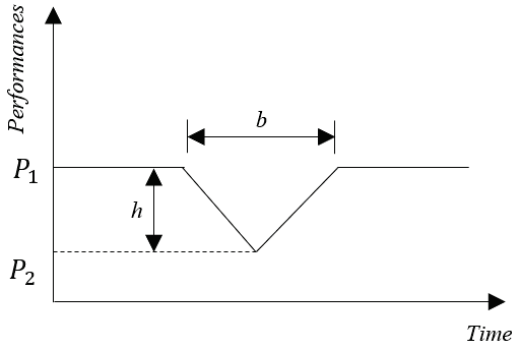

Figure 2 Gradually break in chain functionality [9]

A study by Carvalh, Azevedo and Cruz-Machado on the example of Japan and the earthquake that hit Japan in 2014 identified how the earthquake largely affected resource suppliers, followed by a reduction in available energy, damage to infrastructure, and only end damage to the products themselves that are stored. [10] Thus, although all stakeholders in the chain are equally important for its functioning, without the existence of adequate suppliers it is not possible to ensure the normal functioning of other stakeholders involved in the chain.

3.1 Risks in the Supply Chain

Risks in the supply chain are determined by the context of the supply chain, i.e. the context of the organizations involved in the supply chain. Since the supply chain consists of several interconnected organizations, when analysing the risk, it is necessary to consider the communication of all stakeholders with each other in the chain to identify what is a common weakness, or common risk. [11] In addition to identifying common risks, it is necessary for each stakeholder in the chain to identify for himself, which risks he faces, i.e. which risks characteristic of him could affect the entire supply chain and its functionality. The risks that may

occur in the supply chain can be divided into infrastructure risks, political risks (which include risks of political instability, wars and related events), supply risks, demand risks. [8] It should be emphasized that these risks are just some of the risks that may arise in the supply chain and that the emergence of new risks is primarily determined by the requirements of stakeholders [12]. This is due to the requirements that stakeholders place on the supply chain, and failure to meet such requirements for the organization can mean the risk that may be associated with financial losses, loss of reputation, etc. The impact that risk may have on the organization or supply chain depends on resilience. The greater the resilience, the lower the effect that the risk can have. [13]

All identified risks should be treated, and the treatment of risk depends on the significance of the risk, i.e. on the possible negative impact that the risk may have on the supply chain or the individual organization involved in the supply chain.

All identified risks can be classified into three basic categories, depending on how they will be treated. Risks characteristic of the organization are classified as internal risks of the organization. Risks that are external risks to the organization represent internal risks to the supply chain while risks that are specific to the supply chain environment are classified as external risks to the entire supply chain as a system. Despite the different risk categories, all stakeholders in the supply chain should strive to reduce risk as a different approach may result in the risk being extended to other stakeholders in the chain. In other words, chain stakeholders should share their risk-related experiences and create mitigation plans with other stakeholders who have similar or the same risks.

3.2 Resilience Development Capabilities and Strategies

When it comes to supply chain capabilities in response to threats, there are five basic capabilities that a supply chain needs to have, or that needs to be developed in the supply chain to be resilient:

1) Preventive measures - include activities aimed at reducing the likelihood of risk. They are usually defined for activities that are high risk or are of importance to the functioning of the supply chain.
2) Resistance to consequences - means defining plans and measures that will enable the continuation of the supply chain without the risk of loss of controllability and function.
3) Response plan - means defining plans that will be activated after an event occurs that jeopardizes the functioning of the supply chain.
4) Recovery plan - refers to the actions that will be taken to recover the supply chain after a threat has occurred, i.e. after its performance has fallen due to an adverse event.
5) Continuous improvement - the supply chain and all organizations involved in the supply chain need to constantly improve their system to constantly develop new mechanisms to increase their resilience. [8]

It should be emphasized that resilience in the supply chain can be viewed through three basic levels, the operational level, the tactical level and the strategic level. The operational level emphasizes flexibility, agility and robustness. The tactical level refers to the development of redundancy and system integration while the strategic level refers to cooperation and risk management in the entire supply chain. [14]

4 AN OVERVIEW OF EXISTING RESISTANCE MANAGEMENT MODELS IN THE SUPPLY CHAIN

Research has identified that there are several proposals for resistance management models. Zavala-Alcívar, Verdecho and Alfaro-Saiz base their model on three blocks: the performance management block, the risk management block and, as the last block, they cite resilience itself. They describe how stakeholders and their requirements form the basis for defining the very goal that the supply chain seeks to meet. They talk about risks through the prism of internal and external risks and emphasize the importance of timely identification and development of mitigation plans. [8]

On the other hand, Aguila et.al. in his model describes the resilience index and views resilience through the economic aspect and emphasize that the resilience of the supply chain depends on the economic situation in the system. He also emphasizes that for resistance testing, it is necessary to conduct a simulation using the created model to identify how the supply chain will react if a threat occurs. [15] Vargas and González do not talk about the model of resistance management in the supply chain but describe the indicators that can be used to measure the existing level of resistance. They emphasize that the resilience of the supply chain can be seen through the resilience of the workforce, i.e. employees, the resilience of the business model and finally the resilience of the organization with all components within it. [16] Furthermore, Ouabouch describes only the characteristics that a resistant supply chain should have and emphasizes the redundancy of components as one of the characteristics, ie flexibility. [17]

Ivanov explains that all identified risks related to the supply chain should be adequately treated through risk mitigation measures. However, it does not specify the methodology by which the supply chain could be made resilient, nor does it describe how to manage the supply chain to ensure its resilience. [18]

Thus, it is evident that the authors in their research talk about the importance of developing supply chain resilience but do not define a clear methodology by which organizations could approach the analysis of the current situation and define measures by which the supply chain could be made more resilient. There is a visible need to develop a conceptual model that would enable organizations to design the supply chain based on the principles of resilience or evaluation of the existing level of resilience to increase it.

5 CONCEPTUAL MODEL OF RESISTANCE MANAGEMENT

The conceptual model of supply chain resistance management is shown in Fig. 3.

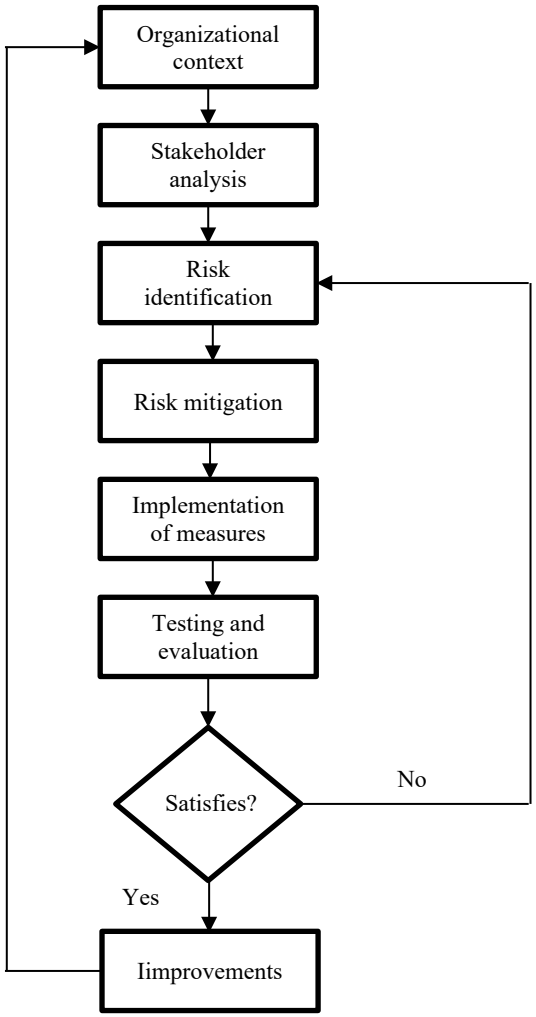

Figure 3 Conceptual model of supply chain resistance

As shown in Fig. 3, the first step in supply chain resilience analysis or management is to determine the context of the supply chain. The supply chain context refers to the general environment in which the supply chain operates, the industrial environment, i.e. the internal environment of the chain itself. Thus, the supply chain should be viewed, i.e. a system consisting of several organizations. However, in addition to this approach, the supply chain can be viewed through the prism of the context of each organization for itself, after which each context of the organization is taken and viewed. In addition to determining the context of the supply chain, it is necessary to analyse the requirements of all stakeholders. Stakeholder requirements are of importance for the supply chain as the supply chain is formed precisely because of the requirements of the stakeholders. Likewise, a change in stakeholder requirements can also result in the emergence of risks, especially in the case of stakeholders with great power.

The next step is to identify the risk. The risks to be identified relate to risks within the supply chain itself, risks related to the general environment, i.e. risks related to the requirements of stakeholders and the possibility for the supply chain to meet such risks. Identifiable risks can be categorized into categories of economic risks, environmental risks and social risks. All identified risks should be analysed and evaluated to identify their impact on the supply chain, i.e. on individual organizations. It is important to note that risk analysis must look at all risks through a partnership approach and that all organizations involved in the supply chain should share their knowledge with others regarding risk analysis and mitigation.

For risks that turn out to be dangerous or critical risks that may jeopardize the functioning of the supply chain, it is necessary to define measures by which they will be reduced or eliminated. All defined measures must be clearly communicated in the supply chain and all organizations must be familiar with the defined measures. Likewise, all defined measures must be implemented in organizations that are affected by risk or may become affected by risk in the future. The implementation of defined measures must be systematic, which means that employee education, infrastructure renovation, implementation of techniques and technology that will be used to monitor risk must be carried out.

To identify the appropriateness of the measures, it is necessary to conduct tests of the appropriateness of the defined measures. Tests should include a simulation of an adverse event and the effectiveness of each organization in responding to the threat. If testing identifies that there is room for improvement, i.e. that the defined measures are not adequate or that not all risks have been identified, it is necessary to re-identify the risks to identify possible risks that were not noticed for the first time.

It should be emphasized that it is necessary to continuously improve the supply chain resilience management system given that the environment in which the supply chain exists is changing and that new risks may arise that will jeopardize the functioning of the chain. Improvements can also relate to the risk analysis process itself, ie determining the context of the supply chain, or to a particular partial part of resilience management.

When it comes to the tools and methods available, Tab. 1 shows some of the tools that can be used to manage supply chain resilience.

Table 1 Tools for managing resistance of supply chain

Phase	Tools
Organizational context	PEST(LE), VRIO, Porter's Five Forces, SWOT/TOWS, ETOP, Vulnerability Assessment, Four Angles Analysis, Resources Analysis
Stakeholder analysis	Stakeholder matrix Salience model, Stakeholder attitude and knowledge map, Influence and Interest stakeholder matrix.
Risk identification	FMEA, 2×2 risk matrix, Monte Carlo, bowtie, HAZOP, Cause Consequence analysis, Consequence/probability matrix, Event tree analysis
Risk mitigation	
Improvement	Pareto diagram, Ishikawa diagram, brainstorming, benchmarking, etc.

Tab. 1 shows only some of the tools that can be used. In practice, there are many more, and their application depends on the needs of the organization.

6 DISCUSSION

The research identified that there are not enough models in the professional and scientific literature that would solve the problem of supply chain resilience. Likewise, it has been identified that the resistance of the supply chain is determined by various factors, primarily the risks that lie within the supply chain itself. In addition to the lack of adequate models, it was identified that the authors emphasize the importance of establishing security stocks that can represent a significant cost to the organization but are a necessary measure to reduce the impact of adverse events or chain disruptions on organizations. In addition to security stocks, the authors stress the importance of selecting multiple vendors of the same resource to disperse risk [19]. However, the selection of several different suppliers in the case of an exclusive supplier of a resource in each area is not possible, which is why there is a need to develop mechanisms to ensure the smooth supply of all resources needed in the supply chain.

A significant risk associated with the functioning of the supply chain is associated with global chains that extend across multiple countries or continents, given that each country has its own context, or each organization involved in the chain may face different risks. [20] It is especially important to note that in such cases organizations can increase their resilience, and thus the resilience of the entire supply chain through the implementation of a security management system consisting of risk management system, quality management system as a core process, business continuity management system, etc., i.e. the integration of the mentioned control systems can significantly increase the resilience. However, since all the mentioned management systems are exclusively intended for organizations and not for the supply chain, the lack of a management system was identified, and then the norms that would cover the area of resistance of the supply chain.

One of the fundamental challenges that organizations may face is a trade-off between efficiency and chain resilience as greater efficiency often requires the elimination or reduction in the number of mechanisms by which efforts are made to increase chain resilience. However, one of the solutions to this problem may be the development of indicators, i.e. the creation of a system based on technologies such as artificial intelligence that can monitor many indicators and signal in time the emergence of risks that may jeopardize the business. So, through the implementation of Industry 4.0 technologies. The supply chain can still be efficient enough but on the other hand, it can also be resilient enough. [21]

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7 CONCLUSION

In this paper, a supply chain resistance management model is described and proposed. The model is based on the principles of quality management, i.e. risk-based approach, evidence-based decision-making, relationship management. This is evident through the emphasis on the need for risk analysis, the involvement of all stakeholders in the supply chain in the adoption of risk reduction measures, and the final decision on the implementation based on analysis using tools and methods. Likewise, the proposed model is in line with the PDCA principle and emphasizes the importance of continuous improvement.

However, a fundamental limitation of this research, and thus of the model, is the insufficient number of professional

and scientific papers covering the area of supply chain resilience. Given this, there is a possibility of upgrading the model based on future research since the proposed model contains within itself the achievements described in other papers that have been improved and converted into a methodology.

The recommendation to future researchers is to upgrade the model by defining indicators that will be selected by the stakeholders in the chain, and which will be used to identify potential risks.

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Authors' contacts:

Matija Kovačić, dr. sc., mag. ing. traff.
University North,
Trg dr. Žarka Doinara 1, 48000 Koprivnica, Croatia
matkovacic@unin.hr

Maja Mutavdžija, dr. sc., mag. ing. traff.
University North,
Trg dr. Žarka Doinara 1, 48000 Koprivnica, Croatia
mamutavdzija@unin.hr

Krešimir Buntak, prof. dr. sc.
University North,
Trg dr. Žarka Doinara 1, 48000 Koprivnica, Croatia
krbuntak@unin.hr

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Utilization of Laboratory Papers with Non-Wood Fibres as Printing Substrates Observed Through the Maximum Ink Penetration Depth

Nicolas Cassel, Justine Chalancon, Hugo Pisaroni, Ivana Plazonić, Valentina Radić Seleš, Irena Bates*

Abstract: The use of non-wood fibres for paper production could be one of the most environmentally friendly and economical alternatives. Reducing the consumption of wood pulp in paper and cardboard production by replacing wood pulp with alternative plant biomass could be a viable solution, as the amount of non-wood fibres in biomass is far from being exhausted. In this study, straw from the most commonly grown agricultural crops in Croatia was used as a source of non-wood fibres. Agricultural residues from wheat, barley and triticale were selected as a substitute for wood fibres for the production of laboratory papers with straw fibres. Under laboratory conditions, straw pulp was mixed with recycled wood pulp in a ratio of 30:70 to produce paper sheets that can be printed with different printing techniques. Regardless of the printing technique used, it is desirable that the prints contain a high-quality reproduction of the image and text on the surface of the paper and that the ink does not penetrate completely through the substrate. In this context, this study observed the use of laboratory-made papers with non-wood fibres as the printing substrate by analysing the maximum depth of ink penetration into the printing substrate obtained with two printing techniques - a modern one (digital UV inkjet) and a very high quality conventional one (gravure). It was found that the gravure printing favoured a greater penetration of the UV ink into the substrate with the addition of straw pulp compared to the digital printing technique. However, this is a consequence of the printing technique, as similar ink penetration was also observed on the laboratory substrate made only from recycled fibres. Compared to commercial papers, the ink penetration is slightly higher into the laboratory made printing substrates. It is interesting to note that the printing substrate with the addition of 30% triticale pulp has the lowest ink penetration, especially in multicolour prints produced with the digital UV inkjet printing technique.

Keywords: digital printing; gravure printing; ink penetration; laboratory paper; non-wood fibres; straw pulp

1 INTRODUCTION

Today, most non-wood fibres in biomass remain unused. This represents a massive waste of raw materials every year, but it is possible to add value to it. In India, for example, straw paper is used every day for printing advertising leaflets. This is also the case in Mexico, where paper made from sugarcane fibres is used to print newspapers. However, these types of paper are not widely used in Europe and it is important to find a way to add value to local biomass waste, as straw waste is abundant in Croatia. Straw is in fact the fastest growing annual fibre source, with a lower lignin content than wood with approximately the same cellulose content. Due to the morphology and chemical composition of the plant, non-wood pulp can be produced at low temperatures with a lower chemical charge than wood pulp [1]. Cellulose-based papers are the most important substrate for the printing industry, where the movement of liquid ink in and between cellulose fibres is largely controlled by the hydrophilic nature of the fibres. When using printing techniques based on small drops of ink (the size of a picolitre) dripped onto the paper surface, the ink begins to penetrate the porous paper substrate. When using uncoated paper as a printing substrate, this behaviour is much more pronounced because uncoated paper is an anisotropic porous medium consisting of bundles of fibres that cross each other in a planar orientation. Since the fibres in the paper are usually impregnated with granular mineral substances as fillers, it has been observed that the liquid as ink penetrating the fiber layer first follows the direction of the fibres and moistens them and then fills the pore space between the fibres [2].

However, the addition of fillers (such as calcium carbonate) to the pulp prior to papermaking has been found to have limited effect on reducing ink penetration, although it does significantly increase the opacity of the paper. On the other hand, the addition of chemicals for internal sizing (hydrophobisation) can significantly reduce ink penetration. [3].

In this study, papers with 30% non-wood fibres (barley, triticale and wheat) and 70% recycled wood fibres were produced under laboratory conditions and then printed using a modern technique that is successfully gaining acceptance in the market - digital UV inkjet printing and a high-quality conventional technique - UV gravure printing. The aim of this research was to measure and compare the penetration of the ink into the paper substrate with the above printing methods when it comes to achieving a quality print. It is known that the absorption of ink into the printing substrate depends on the physical and chemical properties of the substrate, on the properties of the ink, but also on the interactions between the substrate and the ink [4]. Although the ink drying method is similar in both processes, the composition of the ink can vary, leading to different ink penetration results. The main advantage of inkjet printing is that it does not require printing plates or engraved cylinders as is the case with traditional printing methods. In fact, the ink droplets are printed directly onto the surface of the substrate following a digital signal, making the digital printing process less fast and mainly used for short runs [5].

Gravure printing, on the other hand, requires an engraved copper cylinder, which is very expensive, and print runs must be very large (millions of copies) to be profitable.

In this study, a method combining microscopy and image analysis was used to study the penetration of ink into paper substrates. Digital and gravure prints on paper substrates of different compositions (made from recycled pulp or with the addition of straw pulp) were microtomed, scanned with an optical microscope and analysed by image

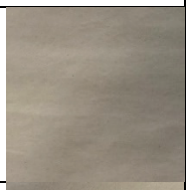
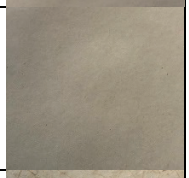
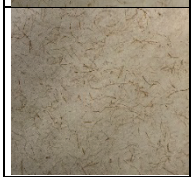
processing. The depth of penetration and the distribution of the ink in the paper were then determined by statistical analysis to evaluate the possibility of using papers with non-wood fibres as a printing substrate.

2 EXPERIMENTAL PART

2.1 Laboratory Papers

Laboratory papers weighing approximately 42.5 g/m^2 were prepared using a Rapid-Köthen sheet former (FRANK-PTI) according to the standard EN ISO 5269-2:2004 [6]. For this purpose, crop residues left in Croatian fields after the harvest of wheat, barley and triticale were collected and cut by hand into pieces up to 3 cm long. The straw, cleaned of grain and impurities, was converted into a semi-chemical pulp using the soda pulping method [7]. The resulting unbleached pulp was blended with a 70% recycled wood fibre pulp, and four types of laboratories produced papers were produced as shown in Tab. 1. In addition to the laboratory produced papers where N was produced from the recycled pulp only (as a reference sample) and 3NW, 3NB and 3NTR were produced with 30% straw pulp, the commercial paper labelled K served as a control sample.

Table 1 Mark and composition of papers used as printing substrates.

Printing substrate				
Mark	Composition		Production	Photography
	Straw pulp	Recycled pulp		
K	0%	100%	commercial	
N	0%	100%	laboratory	
3NW	30% wheat	70%		
3NB	30% barley	70%		
3NTR	30% triticale	70%		

As the commercial paper K is made only from recycled wood fibres, a specific method of ash determination was carried out to estimate the content of mineral salts and other inorganic substances contained in the paper. It is applied to all types of pulp. Whilst most inorganic fillers used in pulp and paper industry do not decompose below 900 °C, calcium carbonate ($CaCO_3$) is an exception, losing carbon dioxide at temperatures above 525 °C. Therefore, if the ash is determined at two different temperatures (900 °C and 525 °C according to TAPPI standards T 413 om-11 and T 211 om-2 respectively) [8,9] it is possible to calculate the percentage of calcium carbonate and clay in paper according to equations (1-2) [10].

$$\mathrm{CaCO_3},\ \% = \left(Ash_{525} - Ash_{900} \right) \times \frac{100}{44} \tag{1}$$

$$\mathrm{Clay},\ \% = \left(Ash_{525} - \mathrm{CaCO_3} \right) \times 1.13 \tag{2}$$

The percentages of calcium carbonate and clay content in commercial paper K were calculated on oven dry-basis, so before sample ignition the moisture content in accordance with the TAPPI standard T 550 om-08 was determined [11].

2.2 Gravure Prints

Gravure printing enables high-quality and consistent reproduction of the finest multicolour details, even in the smallest images, on thin and flexible printing materials in large print runs. This printing process achieves the highest, most consistent print quality with continuous reproduction compared to other printing techniques [12].

In this study, all prepared substrates (Tab. 1) were printed in full tone by KPP Gravure system with 65 Shore impression roller and a 100 lines/inch engraving plate (RK Rint Coat Instrument Ltd) with Solarflex UV-curable inks from Sun Chemicals at a temperature of 23 °C and a relative humidity of 50 %. After printing, the gravure prints were dried using a Technigraf Aktiprint L 10-1 continuous dryer with a light source output of 120 W/cm and an intensity of 60%.

2.3 Digital UV Inkjet Prints

All print substrates were printed using an EFI Rastek H652 digital UV-curable inkjet printer with a resolution of 600 × 600 dots per inch (dpi) (with high quality mode 8 pass) and a print speed of 12.10 m^2/h. This printer uses two double-intensity ultraviolet (UV) lamps with a power of 700 W, which cure UV ink through the shortest curing times and exceptional polymerisation [13].

Inkjet printing is a non-contact technology in which the printing process is based on the ink droplets sprayed from the printhead nozzles. The data of the digital print job is transmitted directly to the inkjet system, which transfers the ink via nozzles to the substrate [14].

In both printing techniques, each printing substrate was printed to achieve a full tone with either: a) one layer of ink (cyan (C), magenta (M), yellow (Y)) or b) two layers of ink,

where one ink is printed over the other, resulting in three different colours: Magenta + Yellow = Red (R), Cyan + Yellow = Green (G), Cyan + Magenta = Blue (B) or c) three layers of ink (Cyan + Magenta + Yellow) (marked as S).

The method of drying UV-curable inks is similar for both processes, with the drying process involving UV radiation to cross-link the organic molecules (monomers) or curing by radiation. The ink used and its interaction with the print substrate determine the thickness of the ink layer on the substrate and thus the overall print quality.

2.4 Preparation of Samples for Microscopic Analysis

After all substrates were printed using both printing techniques, they were cut into 10 × 30 mm strips and placed in an epoxy resin that is a mixture of 88% Epofix resin (containing bisphenol-a-diglycidyl ether) and 12% Epofix hardener (containing triethylenetetramine). The resins were then dried with the test strips for 24 hours at room temperature before being ground and polished with a Buehler grinder and a Struers DAP -V polisher.

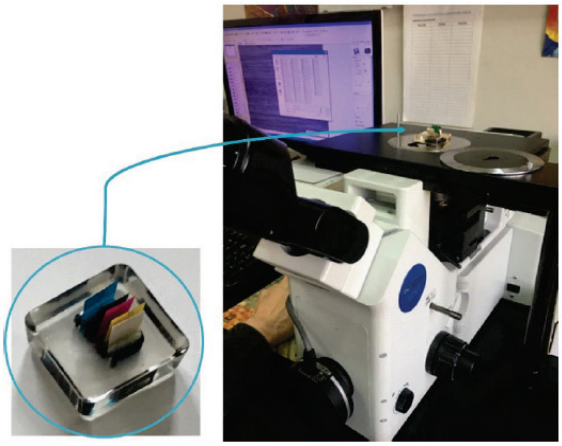


Figure 1 Samples placed in an epoxy resin and examined through the Olympus microscope GX 51 for analysis of the cross section [*15*].

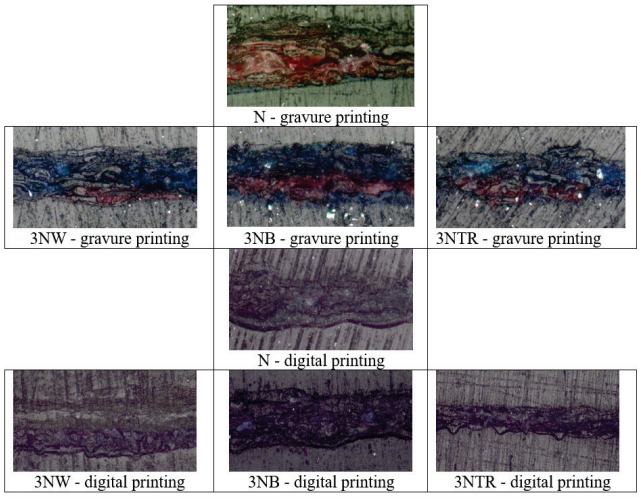


Figure 2 Microscopic images of the penetration of cyan+magenta (B) inks into laboratory papers (N, 3NW, 3NB, 3NTR) printed by gravure and digital printing processes.

The cross-section of the samples was viewed at 200× magnification using an Olympus GX 51 light microscope and analysis software (Fig. 1). The images taken under the microscope (Fig. 2) were further analysed using ImageJ software to measure the maximum penetration depth of inks into laboratory papers with non-wood fibres. The maximum ink penetration depth, referred to as *Hp* in this paper, was calculated according to equation 3 from 20 measured cross-sections of the maximum ink penetration value obtained from each microscopic image. The thickness of the print substrates was also determined from the images taken.

$$Hp = \frac{l}{d} \times 100 \quad (3)$$

Where: l represents the maximum ink penetration value and d is the local thickness of the paper in the measuring section.

3 RESULTS AND DISCUSSION

From a macroscopic point of view, there are differences between printing on commercial and laboratory papers and between printing on papers made from recycled fibres and papers with added non-wood fibres. In fact, wheat, barley and triticale fibres are wider than the recycled fibres, resulting in high local roughness and making it difficult for inks to cover these areas. In recent research [7], it was found that the addition of straw fibres to recycled wood fibre pulp results in papers with a rougher surface by up to 30% (the arithmetic means surface roughness, *Ra*, is 10% higher than papers made from recycled fibres alone).

As the paper used as a control in this research was commercial paper (K) made only from recycled wood fibres, ash i.e. filler content was determined since their presence in printing substrate have significant influence on ink penetration. Results of chemical composition analysis of control paper K is presented in Tab. 2.

Table 2 Chemical composition of control paper substrate K.

w, %	Substrate K
Moisture	3.12 ± 0.38
Ash_{525}	14.12 ± 0.21
Ash_{900}	9.68 ± 0.17
$CaCO_3$	10.10 ± 0.18
Clay	4.54 ± 0.20

First, a comparison was made between commercial paper (K) and laboratory papers with non-wood fibres, considering only prints in one ink layer. Then the same comparison was made, but this time with prints on a reference sample, i.e., laboratory paper made from recycled fibres (N).

In order to achieve a high-quality multicolour reproduction, the prints must be printed in several ink layers. Therefore, an additional comparison was made with multiple ink layers printed according to the recommendations of ISO 12647: Cyan+Magenta (B), Cyan+Yellow (G), Magenta+Yellow (R) and three of these inks (S).

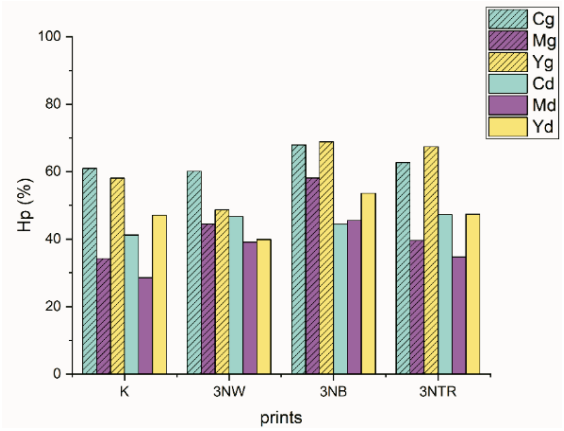


Figure 3 Comparison of the maximum penetration depth of process inks on the control sample (K) and the laboratory papers with non-wood fibres (3NW, 3NB, 3NTR) in gravure and digital inkjet printing processes.

Fig. 3 shows that substrate 3NW (with 30% wheat pulp) has the lowest ink penetration, especially with digital inkjet printing technology. Furthermore, the 3NTR substrate shows similar results to the control paper (K) for both printing techniques, but especially for the digital inkjet technique. The 3NB printing substrate has the highest ink penetration rate of up to 70% achieved in gravure printing, and this high value results in the ink being seen on the other side of the paper. This phenomenon could lead to a reduction in the number of applications for this substrate.

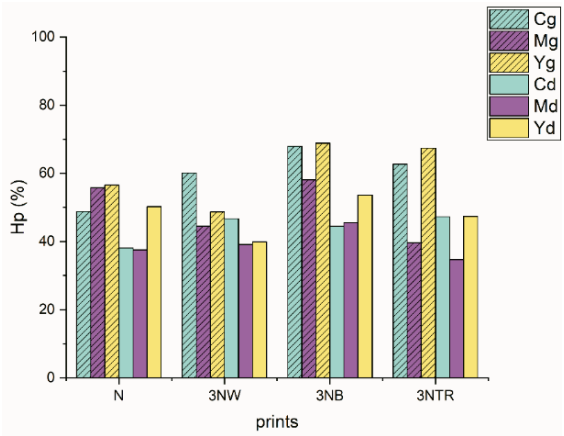


Figure 4 Comparison of the maximum penetration depth of process inks on reference samples (N) and laboratory papers with non-wood fibres (3NW, 3NB, 3NTR) obtained with gravure and digital inkjet printing processes.

The reference paper (N) showed similar Hp values to the laboratory paper with wheat pulp (3NW) for both printing techniques (Fig. 4). In terms of printed ink, the magenta ink penetrates the least through the observed papers (regardless of the manufacturing method). The range of penetration of magenta ink is from 27% to a maximum of 60%, while the range for other inks such as yellow ink is from 39% to a maximum of 76%. The graph also shows that the 3NW paper substrate is better than the 3NB and 3NTR substrates as there is a lower average penetration depth. In the packaging industry, most multicolour prints consist of four primary inks, in some cases even up to 8 inks (CMYK+Pantone). Therefore, it is very important to analyse the ink receptivity on the ink in layers.

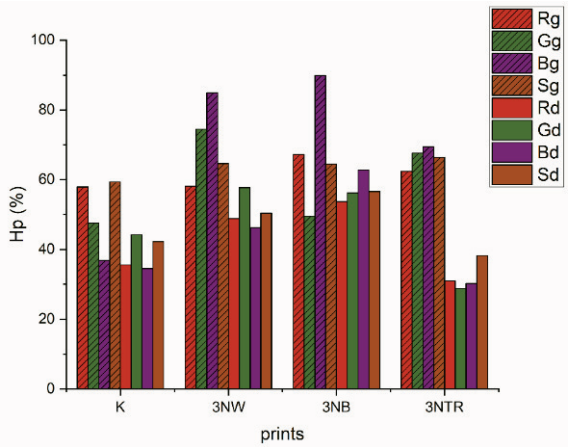


Figure 5 Comparison of the maximum ink penetration depth in two/three layers on the control sample (K) and the laboratory papers with non-wood fibres (3NW, 3NB, 3NTR) obtained with gravure and digital inkjet printing processes.

Fig. 5 shows that the 3NTR print substrate again has an Hp value closest to that calculated for the commercial paper (K). Furthermore, the ink penetration depth achieved on a 3NTR print substrate appears to be constant for all inks applied with the same printing technique. In addition, the Hp values obtained from inkjet ink penetration measurements in the 3NTR printing substrate are lower than those obtained on the commercial paper (K).

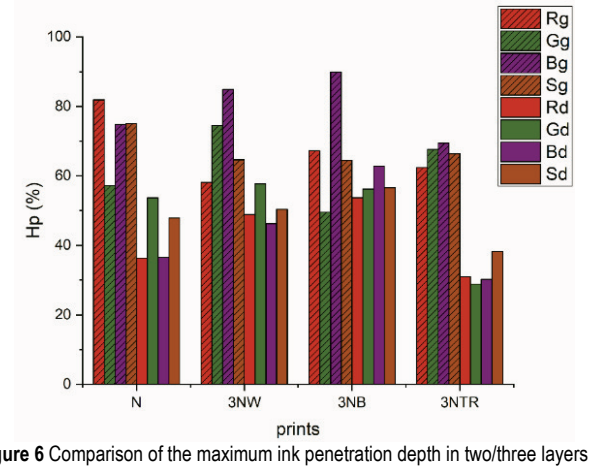


Figure 6 Comparison of the maximum ink penetration depth in two/three layers on the reference sample (N) and the laboratory papers with non-wood fibres (3NW, 3NB, 3NTR) obtained with gravure and digital inkjet printing processes.

The same tendency of the results in relation to the comparison of commercial (K) and laboratory-produced paper (N) can be seen in Fig. 6. In contrast to the gravure prints, laboratory substrates printed with digital inkjet technology show a lower penetration depth of the ink into the substrate, which is most evident in the prints on substrates with barley and wheat pulp. When looking at the inks, it can be seen that the deepest penetration of the ink is achieved by a combination of magenta and cyan ink (marked B), which is up to 90% for prints on substrate 3NB, i.e., in these prints the ink can be seen on the back of the paper.

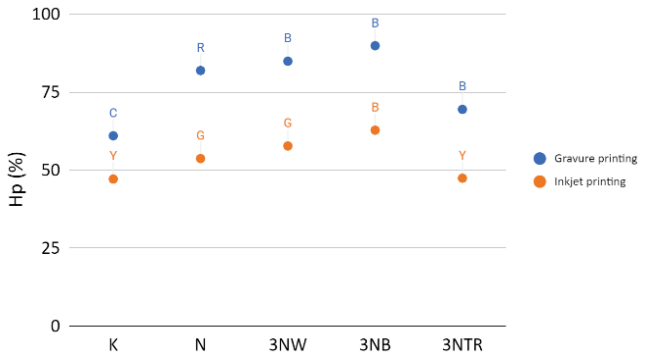


Figure 7 Maximum ink penetration depth for each substrate achieved with a given ink in both printing techniques.

Regardless of the composition and production method of the paper as substrate, the highest value for the penetration depth of the ink is achieved in gravure printing (Fig. 7). From the aspect of ink, in general, the highest penetration, regardless of the type of printing technique and printing substrate, was shown by inks applied in two layers. However, the highest penetration of all inks is observed for cyan+magenta (B) ink into laboratory papers with straw pulp (3NW, 3NB, 3NTR) printed by gravure technique. This can be explained as a consequence of the viscosity of the ink, since inkjet ink is more fluid (10-20 mPa·s) than gravure ink (0.05-0.2 Pa·s) [12]. Furthermore, these results can be explained by the fact that gravure requires a significant amount of pressure (from 0.345 MPa to 0.690 MPa) to be applied to the substrate during printing, in contrast to inkjet printing where the ink penetrates more deeply into the substrate [16].

Furthermore, compared to commercial paper (K), the 3NTR laboratory paper produced with an addition of 30% triticale pulp achieves similar or even better results in multicolour printing in terms of ink penetration for both printing processes. The average ink penetration for the 3NTR paper printed with the digital inkjet printing technique is almost the same as that of the control paper (K), while the lowest average penetration of all the papers examined was achieved with gravure printing on the commercial paper.

These results can be explained by the fact that wheat and barley straw have similar fibre lengths and their distribution is almost equal, whereas this is not the case with triticale straw. The triticale fibres have a much wider length range (from 0.27 mm to 2.63 mm) than the other two straw fibres [17]. Precisely because of the wide distribution of fibre length from short to very long in this type of raw material, there is a reduction in ink penetration through the substrate containing triticale fibres. In commercial paper, many additives are added to the pulp and to the paper surface after sheet formation that reduce ink penetration. For example, fillers such as calcium carbonate, barium sulphate or titanium dioxide are used to make the paper whiter and brighter, and these particle forms can reduce ink penetration. Barium sulphate, for example, has a large and flat shape (similar to a flake) that makes it harder for ink to penetrate the paper.

4 CONCLUSION

Based on the research conducted, we can draw several conclusions:

- The differences between 100% recycled papers and papers made with addition of 30% virgin straw fibres were extremely small from the aspect of ink penetration during printing.
- A modern method of printing, digital UV inkjet, achieves a lower penetration of ink into the printing substrate due to the elimination of high pressure that unavoidable in the conventional printing process.
- Prints on laboratory paper containing 30% triticale pulp, achieve the lowest maximum ink penetration regardless of the printing technique used, proving that this substrate can be used for both monocolour and multicolour printing.
- Although prints on laboratory paper with 30% barley pulp have the highest ink penetration depth, this substrate can be used for single-sided printing without affecting the visibility of the ink on the other side of the paper, e.g., for labels or flyers.

From a development point of view, it would be interesting to carry out analyses on papers made from other biomass-derived fibre materials, such as sugar cane or bamboo fibres, to investigate whether the maximum ink penetration depth is even closer to papers produced in paper mills.

Acknowledgement

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Authors' contacts:

Nicolas Cassel
University of Grenoble, Grenoble INP-Pagora,
461 rue de la Papeterie,
38400 Saint-Martin-D'Hères, France

Justine Chalancon
University of Grenoble, Grenoble INP-Pagora,
461 rue de la Papeterie,
38400 Saint-Martin-D'Hères, France

Hugo Pisaroni
University of Grenoble, Grenoble INP-Pagora,
461 rue de la Papeterie,
38400 Saint-Martin-D'Hères, France

Ivana Plazonić
University of Zagreb, Faculty of Graphic Arts,
Getaldićeva 2, 10000, Zagreb, Croatia

Valentina Radić Seleš
University of Zagreb, Faculty of Graphic Arts,
Getaldićeva 2, 10000, Zagreb, Croatia

Irena Bates
(Corresponding author)
University of Zagreb, Faculty of Graphic Arts,
Getaldićeva 2, 10000, Zagreb, Croatia
irena.bates@grf.unizg.hr

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Study of Indices of Research and Development Management for the Scholar Performance of Scientific Board Members

Amir Khalili, Fereshteh Kordestani*, Yalda Delgoshaei, Ali Hosseini Khah

Abstract: The present research was done with the aim of presenting the aspects and indices of research and development management for the scholar performance of Islamic Azad university scientific board members of Tehran. As a mixed survey, this research is a combination of the quantitative and qualitative research methods. The qualitative part population is the commentators' member of scientific board in Islamic Azad University of Tehran and its sample is 14 people of higher education experts that reached theoretical salivation by 10 people. Data analysis method in qualitative part was done using open, axial and selective coding via interview and Delphi fan methods. The results obtained from the qualitative part showed that the named indices were composed of nine scholar literacy, scientific factors, technical and informational skills, methodological literacy, environmental factors, organizational factors, managerial factors, technological factors and individual properties. This way, totally, 9 aspects, 25 indices and 80 categories were finalized to identify the aspects, indices and categories of research and development management for scientific board member scholar performance of university. In total, management and development indices are among the scholar literacy, scientific factors, technical and informational skills, methodological literacy and environmental factors.

Keywords: Content Analysis; Fuzzy Delphi Analysis; Research and Development Management; Research Performance

1 INTRODUCTION

The origin of many industrial, cultural, social and even military transformation is the knowledge production using the regular and progressive surveys in [1]. Commentators have drawn five major tasks for universities and higher education institutes internationally, having explained their role from mono-entity to multi-role and multi-entity. The most important of these include: educational performance, survey performance, service performance, publication tasks and stuffs occupational growth [2]. In this way, survey performance improvement is one of the university systems missions [3]. In this way, universities and higher education centres attempt to obtain a proper ranking in academic ratings at national and international levels by improving the surveying performance of their scientific board members [4]. Therefore, finding ways to attract, improve and educate committed scholars and the creation of the proper research space are the most important targets of any state universities. According to Van Dinther examination of the scientific board members' performance includes a process that plans the improvement of scientific board members [5]. Thus, as organizations in charge of educating expert human force besides science production, universities require examining their scientific board members' performance. That is because scientific board performance examination causes the clarification of the strengths and weaknesses and provides the grounds for scientific development and achieving the university goals. Despite the variation of the existing examination patterns, most of them are not useful and fully proper to examine the scientific board members' performance at different situations [6].

The scholar seeks to answer the question as to how the proper pattern of survey development and research management activities of Islamic Azad University scientific board members is and what are its aspects, indices and categories, along with filling a part of the existing theoretical gap?

2 RESEARCH PROBLEM STATEMENT AND LITERATURE REVIEW

Khodaey et al. [7] identified 14 aspects, 48 categories and 118 indices as contribution, education, motivation, cognition, self-efficacy, encouragement, structural, managerial factors, clarification, facilities and infrastructures as significant explanations to predict the scientific board members' performance. Shabani Bahar, Qarre and Siavashi [8] introduced survey indices, professional services, scientific publications, education, communication network and English language, as professional aspect indices, organizational communications, documentation, leadership, time management, cost management and team-making as organizational aspect indices and inter-individual, communications, innovation, self-efficacy, autonomy of action and professional ethics as individual excellence indices.

Rastegar et al. [9] consider job performance indices including educational, surveying, professional and individual competence. They examine the existing situation of surveying and professional indices as undesirable, proposing that the regulations related to job performance improvement of professors must be revised and modified. In the research by Ijtihadi et al. [1] presentation of a united system of survey performance examination, without attending the various essence of the majors, neglecting the global experiences over the performance examination and lack of a proper motivation system have caused driving the survey behaviour of scientific board members towards quantity-orientation in research, weak innovation in research and a lack of attending the scientific, research and social responsibilities. Guan Ho, Gowling, Feng and Kai How [10] concluded that formal domestic and international boundaries may impact the

scholars' participation in improving research activities. In line with the findings of Shaban Kareh et al. [6] consider the survey activities indices of scientific board members as follows: formation of scientific seminars and conferences, re-printing the books, arbitration of MA and PhD theses, designing and setting up educational workshops, MA theses and PhD theses director assistant, arbitration of papers and codifying the set of papers, book translation and edition, presentation and execution of research plans, papers published in credible domestic and foreign journals, ability to use electronic resources and databases, and domestic and foreign scientific memorandum.

In addition, in its annual report of survey performance, university of Tarbiyat Modarres has introduced the survey performance indices as follows: participation and presentation of paper in foreign forums, domestic and foreign research plans, grants and activities, received awards for printing scientific-survey papers, participation and presentation of paper in domestic forums, receiving incentive survey bonus, observation of the cases related to safety in projects, laboratory works, using the workshop, laboratory and library space, connection with foreign research institutes, documentations [11] in Scopus, Clarivate and Laden, number of domestic inventions, number of international inventions, number of membership in international forums, number of study opportunities, number of contributing to superior theses, number of intra-university research plans, searching for research needs of various organizations, cooperation with busy employers of university survey projects, participation in improving quality indices of university library, electronic publications, electronic content and its update, personal strategies and prosperity, authorizing the superior books of the year, presence in web and virtual research.

It should be noted, in turn, that the university survey system is facing numerous problems that make improving and research and development management performance of survey activities difficult. Weakness of informing system and deficiency in information management and classification [12] and inaccessibility to the surveys done at national and international levels, along with shortage of research budget, lack of transparency, lack of application are among the unique problems our scientific and survey system suffers from. As a result, due to inability in collecting, documenting, organizing, storing, sharing and spreading information on time, many survey activities become iterative and decisions are not made influenced by information shortage and a lack of on-time and proper information sharing and enough power [13].

It should be noted that asymmetrical distribution of knowledge resources, technology and the requires of activity in the globalization era, have made universities tending to novel methods to improve research development management activities, thus increasing interaction in national and international levels to access such resources. It has provided further grounds to improve and examine survey performance until reaching the global standards level [14].

In this way, it seems that in the Islamic Azad University, too, the central organization can be effective on accelerating the move to reach a logical balance in improving the research and development management. Creation of scientism research grounds, grounds for further communications of scholars and the grounds for quantitative and qualitative improvement of survey performance and the eventual creation of a competitive space, take a constructive and effective step in the order of university excellence in the area of conducting various scientific surveys [11].

3 RESEARCH METHOD

The present research is qualitative in terms of nature. It is library and field and cross-sectional study in terms of data collection method. It is descriptive in terms of research execution method and it is fundamental based on objective. The data investigated in the survey is a mixture of quantitative and quantitative type. Data analysis method is interview, of content analysis type. For this purpose, keywords were determined and searching the related resources and papers was done in databases (ProQuest, Springer, Science Direct, Sage, Eric, Google Scholar) and Persian databases (JADA, MAGIRAN, DANESHYAR, NOORMAGS) in 2000 to 2020.

Table 1 Terms of criterion and databases searched in survey

Terms searched	Databases searched	Number of papers obtained		Papers selected
		Research	Review	
Research performance, research performance of board, research performance of university	ProQuest Springer Science Direct Emerald Sage Eric Google Scholar	33	17	14

The papers obtained were investigated and verified by two experts. In addition, by investigating the papers and theoretical backgrounds, the essential variables of this area were extracted. Initial pattern, questions of interview with experts were codified to explain the aspects, indices and categories of research management and development. Experts' sampling was done from purposive sampling. The number of experts in the scientific board performance was ten. Whereas interviews were done until 14 people. The main criteria of experts' selection were enrichment in terms of survey problem and objectives, research experience, membership of university or research centres scientific boards in the areas of education, survey and research management. The reason for selecting people was that they are directly involved in scientific board performance and have the motivation required to explain research and development management to examine the scientific board members' performance and the examinations thereof. The semi-structured interviews were employed for qualitative data collection of the survey. During the interview, by asking guidance questions, the scholar controlled the correctness of his/her impressions from interviewees' speeches. To ensure similar data sufficiency and qualitative data analysis, MAXQDA12 software was used for coding and classification.

Data analysis methods of the present research were the content analysis based on fuzzy Delphi analysis. By analysing and summing the attempts of other scholars of content analysis, presented a three-phase process for content analysis that includes open, axial and selective coding for integration through prevalent contents. In open coding, an attempt was made to describe and code the categories of participants' speeches of importance. However, the interpretation of the meanings of such categories was not considered. In this survey, in the axial coding level, the reproduced codes in the previous stage were integrated or placed below one another by interpreting the open codes meanings and over progressive and iterative comparisons with them. In the third level, namely the selective coding, a number of prevalent contents were identified that expressed the key research concepts. Such contents were based on interpretative contents and had a higher level of singularity. In this stage, any theoretical ideas that form the research foundation, were directly employed. In the following, an attempt was made to make the number of prevalent codes constrained as much as possible and to make them relevant to a reasonable minimum of interviews. It can be noted that the triple levels of descriptive and interpretative coding were done integrated. It means that at first, all codes were coded as descriptive at all interviews. After the completion of descriptive coding, their progressive comparison would drive the scholar to interpretative codes. In this way, the set of clusters would be gradually completed. And prevalent contents emerged by interpreting and clustering them at a higher level. Delphi techniques are a robust process based on the group communicating structure that is used with the aim of achieving collective census among experts in cases where incomplete or uncertain knowledge is available. Since the possibility of uncertainty is compatible with fuzzy sets, it is thus better that data are taken from experts in the form of natural languages and are analysed using fuzzy sets. For this purpose, the proposal of integrating traditional Delphi method with fuzzy theory has been provided under the name of fuzzy Delphi method.

3.1 Research Findings

3.1.1 Content Analysis Findings

Through careful, line-by-line studying of interviews, descriptive contents were attributed to every piece of sentences by the scholar. Often, the sentences took various codes from various perspectives and were labelled to data identical to each other in terms of concept with proper names. The concepts extracted in this section have been classified in Tab. 1. The outcome of this level was the production and extraction of 209 references to interviews in the form of 87 codes.

Table 2 Referenced Codes

Employment in organizations	Connection with schools	Recruiting and selection type
Examinations and critiques	Connection with industry	Book criticism and correction
Clear organizational objectives	Connection with media	Discipline in work
Social communications and community criteria	Conduction of joint survey activities with university students	General skills of the web and social networks context
Familiarity with search methods	Commercialization of researches results	Speech-making skills
Email	Joint book composition and translation	Basic research skills
Book translation	Endurance and continuation	Advanced research skills
Research-orientation of organization	Rewards	Skill in applying information
Research-orientation of leader	Creation and management of research teams	Paper in non-professional journals
Scientific single-notes	Participatory decision-making	Interpretive papers
Occupational and organizational commitment	Critical book correction	Positive participation
Technical knowledge generation	Recognition of information required	Private section participation
Sufficient personal motivation	Mastery over English language	Responsibility
Being welcome	Globalization of the research and scholar	Control center
Self-efficacy	Organizational atmosphere	Participatory management
Inherent creativity	Survey plans arbitration	Information management
Creativity in research	Research papers and journals arbitration	Speech-making in public forums
Professional Curriculum design	Obtaining ranking in national survey festivals	Joint survey activity with abroad
Self-esteem	Decentralized structure	Organizational culture
Lack of pride and arrogance	Executive record in holding conference	Membership in professional forums
Decentralization in organization	Participatory leadership	Research publications scientific board member
Connection with professional research networks	Correct and updated information finding behaviours	Professional social networks such as Research Gate, Medley, LinkedIn, Academy
Having professional software of work domain	Not involving personal biases in research	Designing and setting up of laboratory and workshop
Number of papers indexed in foreign databases	Ability to use electronic resources and databases	Advanced, rather than general, information search
Promotion of employing novel research technologies	Number of documentations as per papers and book	Having general skills of working with computer
Presentation of paper in international forums	MA and PhD these arbitration	Theses guidance and consultation
Publicly perceivable books composition-such as children and youths	Scientific investigation, criticism and revision of books and papers	Holding annual research exhibitions
Attending entrepreneurship at all sections, such as agriculture, sports	Presentation and execution of research plans inside and outside the university	Familiarity with novel science and technology advances
Familiarity with quantitative and qualitative research methods	Familiarity with statistical and analytical software	Re-printing and revising the books composed

In the axial coding level, interpretive codes were generated using the progressive and iterative comparison of the descriptive codes produced in the previous stage. To produce interpretive codes, several descriptive codes were collected in the sub-set of an interpretive code and formed it. These axes include the following:

Table 3 Surveys

Survey	Technical skills	Scholarly
Bounding of industry with university	Speech-making	Scientific arbitration and assessment
Communications	Personality characteristics	Laboratory experience
Participatory management	Working skills	Informational literacy
Leadership properties	Organization culture	Globalization
Software skills	Structural factors	Professional publications
Research method skill	Occupational factors	Composing book
IT	Incentive systems	Scientific papers
Computer literacy	Critical perspective	

Given the concepts obtained from the previous level, in the selective coding level, by conducting several studies, re-investigating and the commutation process among the notions and categories, the results of the main and fundamental studies related to that category were located near each other given the studies specific to any category. And by investigating the role of factors and their impact on research and development management for survey performance, the relation between categories and strategies was identified and analysed. Finally, the result was 9 main codes that denote the surveying performance aspects and 25 axial codes that denote the categories of aspects. In addition, 80 open codes were specified that reduced to 60 open codes after integration. A full description of the formation of aspects, categories and indices have been shown in table4.

Table 4 Selective coding

Aspects	Categories	Indices
Environmental factors	Research globalization	Globalization of survey and scholar Bounding of industry with university
	Bounding of industry with university	Existence of widespread survey connections Commercialization of researches results Contribution of private and industrial sector
Managerial factors	Communications	Connection of scholars with media Connection of scholars with educational centres and schools Social connections and community criteria Relation with professional research networks
	Participatory management	Participatory decision-making Participatory management Research-oriented leader
	Leadership properties	Participatory-oriented leadership Familiarity with statistical and quantitative and qualitative research software
Methodological literacy	Software skills	Familiarity with statistical and quantitative and qualitative research software Using working domain professional software
Technological factors	Research method skill	Advanced research skills Basic research skills Familiarity with research methods and quantitative and qualitative analysis
	IT	Familiarity with novel science and technology advances Promotion of using novel research technologies
	Computer literacy	General skills of web domain and social networks Having general skills of working with computer Email and using it
Surveying literacy	Scientific papers	Papers indexed in foreign databases Interpretive papers
	Scholarly	Presenting paper in international forums Paper in non-professional publications
	Ability to examine and scientific arbitration	Professional research networks such as Research Gate
	Laboratory experience	Executing research plans inside and outside university Conduction of joint research activities with students
	Informational literacy	Number of documentations as per papers and book Scientific single-notes
	Technical skills	Creation and management of research teams MA and PhD theses guidance and consultation
	Having speech-making skills	Joint survey activity with abroad Survey plans arbitration Survey publications and papers arbitration
	Personality characteristics	Arbitration in forums and conferences Setting up laboratory and workshop in the professional domain
Technical and informational skill	Working skills	Research (methodology) training workshops Recognition of information required Using electronic resources and databases Advanced, rather than general information search Obtained information management
	Organization culture	Correct and updated information finding behaviours Technical knowledge production Mastery over English language Having rhetorical skills Making speech in public forums
Individual properties	Structural factors	Creativity Self-esteem Self-efficacy Control centre Openness

Organizational culture	Occupational factors	Lack of pride and arrogance Sufficient personal motivation and ability Responsibility Discipline at work Endurance and continuation
	Incentive systems	Vivid organizational objectives Research-oriented organizational atmosphere Survey-oriented organizational culture Decentralized structure
	Critical perspective	Decentralization in assigning survey affairs Recruiting type Job and organizational commitment Existence of types of rewards Existence of systems to resolve scholars' barriers Scientific investigation, criticism and revision of papers Students' theses arbitration
Scientific factors	Composing book	Book criticism and correction Criticism and commenting on social problems in professional context in newspapers Publicly perceivable book composition Book composition and publication in professional domain Re-printing and revising the composed books Translating updated books in professional domain Scientific board member of research publications
	Membership in professional publications	Membership in professional forums Gaining ranking in national survey festivals

3.1.2 Fuzzy Delphi Findings

For this purpose, the view of the experts interviewed on the importance and priority of each of the indices was collected. On this basis, the indices effective on survey performance were identified and research management pattern was codified. In this survey, triangular fuzzy numbers were employed to make experts' views fuzzy.

Table 5 10-degrees fuzzy spectrum for indices valuation

Finite equivalent	Lingual variable	Fuzzy number scale
1	Very unimportant	(1,1,1)
2	Very unimportant to unimportant	(1,2,3)
3	Unimportant	(2,3,4)
4	Unimportant to medium importance	(3,4,5)
5	Medium	(4,5,6)
6	Medium to important	(5,6,7)
7	Important	(6,7,8)
8	Important to very important	(7,8,9)
9	Very important	(9,9,8)

In the next step, fuzzy average and fuzzy means of people's scores must be computed. To compute the average opinions of n respondents, fuzzy average was computed as follows: Every triangular fuzzy number has been displayed for each of the indices as follows in Eq. (1) to Eq. (4):

$$\hat{f}_j = (l_i^k, m_i^k, u_i^k) \tag{1}$$

$$L_j = \min(X_{ij}) \tag{2}$$

$$M_j = \sqrt[n]{\prod_{i=1}^{n} X_{ij}} \tag{3}$$

$$U_j = \max(X_{ij}) \tag{4}$$

Index i refer to the expert, such that τ_j is fuzzy average of JTH criterion, X_{ij} is examination value of ITH expert from JTH criterion, L_j is minimum value of examinations for JTH criterion, M_j is geometrical average of experts examination value of JTH criterion performance, U_j is maximum examinations value for JTH criterion.

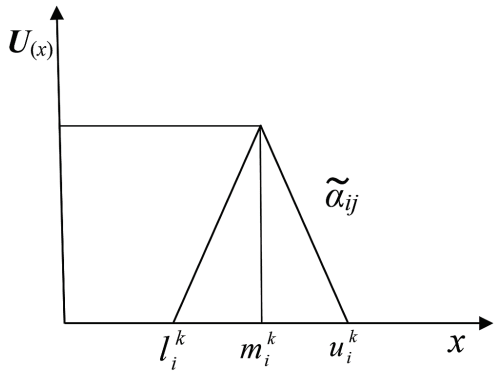

Figure 1 Valuation of indices relative to each other using triangular fuzzy numbers

In fact, these aggregation methods are experimental methods provided by various scholars. For example, they have considered a conventional method to aggregate a set of triangular fuzzy numbers as minimum i and average m and maximum u that is shown in Eq. (5)

$$F_{AGR} = \left(\min\{1\}, \left\{ \frac{\sum m}{n} \right\}, \max\{u\} \right) \tag{5}$$

In this study, fuzzy average method has been employed. Fuzzy average of n triangular fuzzy numbers was computed using Eq. (6):

$$F_{AVE} = (L, M, U) = \frac{\sum_i^k l}{n}, \frac{\sum_i^k m}{n}, \frac{\sum_k^i u}{n} \tag{6}$$

Where triangular fuzzy number of $\hat{f}_j = \left(l_i^k, m_i^k, u_i^k\right)$ is the fuzzy equivalent of KTH expert opinion over ITH criterion. Fuzzy average of experts' panel view for each of the research indices has been brought in the table. In addition, Eq. (7) was used for defuzzification.

$$DF_{ij} = \frac{\left[(u_{ij} - l_{ij}) + (m_{ij} - l_{ij})\right]}{3} + l_{ij} \quad (7)$$

In the executive phase of fuzzy Delphi, after the codification of the initial model, the questionnaire containing questions over the aspects and indices was codified and assigned to the selected people. To investigate the validity of the model designed, model number 2 was codified and was again sent to experts for the second round. In this way, all experts became aware of the outcome of the opinions of one another. The results implied that 9 factors and their indices were effective on research and development management and survey performance examination and all experts were census on it.

Fuzzy average and the de-fuzzified outcome of the values related to indices were computed. The threshold value was set as 0/7 in this research. The de-fuzzified value greater than 0/7 is accepted and any index having a score lower than 0/7 is rejected. At the end of the first level, all the items having a score lower than 0/7 were eliminated. In the second level, fuzzy Delphi analysis continued for the remaining indices. The results obtained from the elements de-fuzzification in the second level and the difference of the fuzzified values of the first stage and second level have been reported in table6. Evidently, due to the high number of categories and indices, bringing fuzzified averages tables as per fuzzified values (U, M, L) has been refused.

Tab. 6. Fuzzified values of the first and second level and their difference

Table 6 Fuzzified values of the first and second level and their difference

Indices	First round	Second round	Difference
Holding annual research exhibitions	6.09	6.09	0
Globalization of research and scholar	6.09	6.09	0
Participatory decision-making	5.96	6.09	–0.13
Participatory management	6.09	5.96	0.13
Ability to use electronic sources and informational databases	5.96	6.09	–0.13
Participatory leadership	6.05	6.09	–0.04
Commercialization of research results	6.09	6.09	0
Private sector contribution	6.09	6.05	–0.04
Rewards	6.13	6.09	.0
Designing and setting up research training workshops and laboratories	5.92	6.09	–0.17
Familiarity with search methods	6.09	6.09	0
Recognition of information required	6.09	6.05	0.04
Research-oriented leader	6.09	6.09	0
Advanced, rather than general search	5.92	6.09	–0.17
Information management	6.09	6.09	0
Information skill	6.09	6.09	0
Mastery over English language	6.09	5.97	0.12
Technical knowledge production	.5	.5	-
Creativity and innovation in survey	7.15	6.8	0.35
Self-esteem	5.3	5.96	–0.66
Having work domain professional software	6.09	6.09	0
Control centre	6.09	6.09	0
Sufficient personal motivation and ability	6.09	6.09	0
Responsibility	5.92	5.72	0.2
Having general skills of working with computer	6.27	6.09	0.18
Lack of centrality in organization	6.09	6.09	0
Email	7.15	6.96	0.19
Presenting paper in international forums	6.8	5.92	0.88
Paper in non-professional publications	6.06	6.09	–0.03
Number of papers indexed in foreign databases	6.17	6.09	0.08
Interpretive papers	2.31	6.09	–3.78
Number of documentations as per papers and book	6.41	6.09	0.32
Scientific single-notes	7.54	6.77	0.77
Presenting and executing survey plans inside and outside university	6.47	6.89	–0.42
Conducting joint survey activities with students	7.31	6.58	0.73
Creation and management of survey teams	5.96	5.96	0
Book translation	5.92	5.68	0.24
Papers and surveys plan arbitration	6.09	6.09	0
Professional curriculum designing	6.09	5.92	0.17
Scientific board member of survey publications	5.33	5.68	–0.35
Membership in professional forums	6.22	6.11	0.11
Obtaining ranking in national survey festivals	6.55	6.17	0.38
Familiarity with statistical and analytical software-qualitative research software	5.96	6.09	–0.13
Self-efficacy	6.09	5.92	0.17
Advanced research skills	6.06	6.09	–0.03
Basic research skills	5.86	6.09	–0.23
Familiarity with quantitative and qualitative research methods-statistics analyse	5.96	6.53	–0.57
Connection with media	6.09	5.97	0.12
Connection with industry	6.15	6.27	–0.12
Research-oriented organization	6.3	5.96	0.34
Connection with professional research networks	7	6.96	0.04
Speech-making skills	7.24	6.92	0.32
Making speech in public forums	6.53	6.09	0.44
Familiarity with novel science and technology advances	6.31	6.09	0.22
Promoting the usage of new research technologies	7.41	6.72	0.69
Organizational atmosphere	6.09	5.92	0.17
General skills of web domain and social networks	7.15	6.89	0.26

Decentralized structure	5.91	6.09	–0.18
Correct and updated information finding behaviours	6.96	6.09	0.87
Inherent creativity	6.72	6.27	0.45
Discipline at work	5.96	5.92	0.04
Endurance and continuity	5.92	6.09	–0.17
Vivid organizational objectives	5.92	6.09	–0.17
Social communications and community criteria	6.09	6.8	–0.71
Professional social networks such as Research Gate, Medley, LinkedIn, Academy	5.97	5.92	0.05
Organizational culture	6.09	6.09	0
Papers and survey publications arbitration	6.09	6.09	0
Executive record in holding conference	5.72	5.96	–0.24
Laboratory and workshop designing and setting up	5.92	6.09	–0.17
Occupational and organizational commitment	5.68	6.09	–0.41
Examinations and criticisms	5.92	5.96	–0.04
Critical book correction	5.72	6.09	–0.37
Scientific investigation, criticism and revision of books and papers	5.57	5.92	–0.35
Book critique and correction	5.92	5.96	–0.04
Publicly perceivable book composition- scientific book composition in children and youth's language	5.92	5.92	0
Book composition, translation and conference	5.74	6.09	–0.35
Re-print and revision of the books composed	6.09	5.79	0.3
Joint survey activity with abroad	5.92	6.09	–0.17
MA and PhD theses arbitration	5.92	5.72	0.2
Theses guidance and consultation	6.09	5.92	0.17

The difference of the fuzzified average of the experts' opinion is lower than 0/7 in both levels, experts have reached census in terms of the aspects, categories and indices of research and development management to assess the scientific board members' performance and the enquiry ceased in this level and all the aspects, indices and categories were verified in the second level and 80 out of 87 content analysis indices were recognized as proper.

4 CONCLUSION

In this section, 9 aspects such as survey literacy, scientific factors, technical and informational skill, methodological literacy, environmental factors, organizational factors, managerial factors, technological factors and individual property were extracted with 25 indices, as explained in Tab. 3. Five main aspects were considered.

The first aspect is the survey literacy that expresses the scientific papers composition, scholarly and the ability to arbitrate, assess and laboratory experience. These results are in line with the surveys by Shabani et al. [8], Forutan and Reshadatjou [15], Shaban Kareh et al. [6] and the formal report of the university of Tarbiyat Modares [11] that highlight survey papers composition, professional books, papers indexed in professional databases, conduction of survey plans inside and outside the university, creation and management of survey teams, joint survey activities with abroad, arbitration of survey plans and the papers of the others in the professional context and the setting up of various workshops and laboratories. The only difference that can be found between the previous works done and the present survey is the extraction of indices as a set and the identification of their indices to advance, improve and assess the survey performance research and development management among the scientific board members when they have been attended in a dispersed manner in the past surveys.

The second aspect is the scientific factors that express publicly perceivable books composition, conferences and the book and paper translation, guidance and arbitration of theses, professional publications and journals and receiving national and international rewards and they are in line with the surveys by Shams [16] and Chen et al. [10] that highlight the scientific criticism and revision, theses arbitration, book criticism and correction, social opinion and criticism, scientific books composition in plain language, re-printing the books and the globally updated books. The only difference that can be found between the previous works done and the present survey is the extraction of indices as a set and the identification of their indices to advance, improve and assess the survey performance research and development management among the scientific board members when they have been attended in a dispersed manner in the past surveys.

The third aspect is technical and informational skill that expresses the informational literacy and technical and speech-making skills. These results are in line with the surveys by Shabani et al. [8], Cherani et al. [2], Shams [16] and Riahi and Sharafi [17] that highlight the recognition of the information required, the ability to use electronic resources and databases, advanced information search, obtained information management, technical knowledge production, mastery of English and having rhetorical skills and making speech in public forums. The only difference that can be found between the previous works done and the present survey is the extraction of indices as a set and the identification of their indices to advance, improve and assess the survey performance research and development management among the scientific board members when they have been attended in a dispersed manner in the past surveys.

The fourth aspect is methodological literacy that expresses the software skills and research method skill. These results are in line with Shams [16], Jacob et al. [18], Rastegar et al. [9], Ijtihadi et al. [1] and Riahi and Sharafi [17] that highlight the familiarity with statistical and analytical software, quantitative and qualitative software, having professional context mining software and employing them, advanced and basic research skills. The only difference

that can be found between the previous works done and the present survey is the extraction of indices as a set and the identification of their indices to advance, improve and assess the survey performance research and development management among the scientific board members when they have been attended in a dispersed manner in the past surveys.

The fifth aspect is environmental factors that expresses the globalization of the survey and the bounding of industry with university and widespread communications. These results are in line with the surveys by Shaban Kareh et al. [6], and the report by the university of Tarbiyat Modares [11] that highlight the globalization of the scholar and survey, the bounding of the industry with university, the existence of widespread survey connection, commercialization of researches results, contribution of private and industrial sectors, communications of scholars with media, industry, educational, research centres (technology parks), as well as social communications and community criteria. The only difference that can be found between the previous works done and the present survey is the extraction of indices as a set and the identification of their indices to advance, improve and assess the survey performance research and development management among the scientific board members when they have been attended in a dispersed manner in the past surveys.

The sixth aspect is organizational factors that expresses the organizational culture, structural factors (personality and individual features), occupational factors and incentive systems. These results are in line with Forutan and Reshadat Jou [15], Khodaey et al. [7], and Asnafi, et al. [19] that imply such indices as clear organizational objectives, research-oriented organizational atmosphere, survey-oriented organizational culture, decentralized structure, occupational commitment, creativity, heuristics, organizational innovation, existence of types of rewards and the existence of systems to resolve the scholars' barriers. The only difference that can be found between the previous works done and the present survey is the extraction of indices as a set and the identification of their indices to advance, improve and assess the survey performance research and development management among the scientific board members when they have been attended in a dispersed manner in the past surveys.

The seventh aspect is managerial factors that expresses the participatory management and the features of leadership. These results are in line with the researches by Khodaey et al. [7], Haustein et al. [20], Shams et al. [21], Muhammadi and Qazanfari [22], Shaban Kareh et al. [6] and Benbow et al. [23] that highlight participatory decision-making, participatory management, research and development orientation of the leader and participatory-oriented leadership. The only difference that can be found between the previous works done and the present survey is the extraction of indices as a set and the identification of their indices to advance, improve and assess the survey performance research and development management among the scientific board members when they have been attended in a dispersed manner in the past surveys. The previously mentioned surveys that were in line with the results of present research, differ from the present research in that each of them has investigated some aspects of the present survey and a united survey has not been conducted in the name of the present survey. Each of them has investigated separate variables and different aspects of the research and development management to improve and examine the surveying performance. And a background over the identification of the indices and categories of surveying performance thoroughly is barely seen. In this way, the present survey has been done given the importance of the subject of research development and management to improve and assess the surveying performance, and given the lack of the conduction of university studies in this context. The tendency of scientific and scholarly communities domestically and abroad will be towards research and development with scientific management.

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Authors' contacts:

Amir Khalili, PhD student
Department of Educational Management,
Faculty of Psychology and Educational Sciences,
Central Tehran Branch, Islamic Azad University,
Shahid Khandan St., Sohanak, Tehran, Iran
E-mail: amir_khalili2010@yahoo.com

Fereshteh Kordestani, Assistant Professor Dr.
(Corresponding author)
Department of Educational Management,
Faculty of Psychology and Educational Sciences,
Central Tehran Branch, Islamic Azad University,
Shahid Khandan St., Sohanak, Tehran, Iran
E-mail: fe.kordestani92@gmail.com

Yalda Delgoshaei, Assistant Professor Dr.
Department of Educational Management,
Faculty of Psychology and Educational Sciences,
Central Tehran Branch, Islamic Azad University,
Shahid Khandan St., Sohanak, Tehran, Iran
E-mail: y.delgoshaei@gmail.com

Ali Hosseini Khah, Assistant Professor Dr.
Kharazmi University, Mofateh St., Tehran, Iran
E-mail: h.ali@khu.ac.ir

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Maximization of Solar Radiation for Fixed and Tracking Surfaces in Antalya Province of Türkiye

Batur Alp Akgül*, Fatih Alisinanoğlu, Muhammet Fatih Hasoğlu, Mustafa Sadettin Özyazıcı

Abstract: Solar energy has gained increasing importance in today's world and become a viable primary energy source in the recent decade. Solar radiation obtained by the solar surface is highly affected by its orientation, azimuth, and tilt angles. Therefore, in this study, the performances of the fixed-axis system, one-axis, and two-axis solar tracking systems are investigated to enable maximal solar radiation in solar systems to be installed in Antalya by using climatic and latitude data provided by NASA. Furthermore, the optimal tilt angles are determined by examining the values of angles for which the total solar radiation falling on the tilted surface is maximal. The case study and measurement data investigations are conducted for the four districts of Antalya. The obtained radiation values throughout the year for one-axis and two-axis solar tracking systems are compared to an annual fixed system for evaluating the existing solar potential in Antalya province. Besides all these, solar system cost analyses including the average payback period for residential, commercial, and large-scale solar systems based on LCOE are investigated. The proposed methodology can be implemented for performance and cost analysis of the solar potential in a certain location of Türkiye and extended to any place in the world.

Keywords: cost analysis; fixed; optimal tilt; radiation; solar energy; tracking

1 INTRODUCTION

Nowadays, researchers are more concentrating on solar systems to meet the increasing energy demands of countries. Each region has its unique position in terms of solar radiation. Solar radiation data has a crucial role in solar systems for optimal design and size to be installed solar system in the region. Total solar radiation values for the region to be installed solar systems are the most crucial metric for determining energy generation. The efficiency of the solar surface extremely depends on its orientation, material characteristics, climatic conditions, seasonal variations, and geographical location as well as period of usage. The optimal tilt angle is dependent on latitude, solar declination, and the time and days in the year [1-3]. For this reason, the tilt angles of solar surfaces should be adjusted monthly, seasonal, or annual to obtain maximal solar radiation from solar surfaces.

This paper aims to investigate each optimal tilt angle for monthly, seasonal, and annual and to maximize total radiation falling on a tilted solar surface for the districts of Antalya which is located in the southern part of Türkiye. The regional calculation of the optimal tilt angles using the proposed model, obtaining the total solar radiation of one-axis and two-axis solar tracking systems, and comparison to a fixed system is one of the objectives of this study. It is also aimed to evaluate the results by calculating the optimal tilt angles to maximize the efficiency of fixed and tracking solar systems based on four districts of Antalya.

The outline of this study is as follows: The first section presents the introduction and objectives of this study. In the second section, a literature review and related works are presented. Materials and procedures are described in the third section such as the case study region, used data, theoretical analysis, description of the algorithm, and calculation model. In the fourth section, solar system cost analysis for residential, commercial, and large-scale solar systems based on *LCOE* are investigated and the average payback period is determined. In the fifth section, calculations, results, and discussions are presented specifically by focusing on optimal tilt angle values, solar radiation gains, performance analysis, and comparison of fixed systems and tracking systems carried out. The conclusions of the study are presented in the last section where also suggestions for improving the efficiency of solar systems are noted. This research is limited to the geographical region of Antalya province in the Mediterranean region of Türkiye.

2 LITERATURE REVIEWS AND RELATED WORKS

In Türkiye, several studies in the literature have been carried out by the researchers for different purposes and regions about optimization of tilt angle, the orientation of solar surfaces, and calculation of solar radiation values. Most of the studies to determine the solar radiation potential of a certain location were focused on the determination of total radiation falling on a horizontal surface using measured data [4-7]. Several solar radiation calculation models are performed in the literature by using Artificial Neural Networks [8, 9] and Machine Learning [10, 11]. The studies were carried out optimization of tilt angles and maximization of solar radiation falling on the tilted surface for the different locations are contributed to Türkiye in this field [12-16]. Besides, there are different studies in the literature to provide maximal radiation with solar tracking systems and compare radiation values with fixed systems for Türkiye [17-21].

It is well-known in the literature that the tilt angle is an important parameter to obtain maximal radiation efficiency. In literature, there exist some studies which focused on the calculation of the total solar radiation components to find the optimal tilt angle. Additionally, although there are a few studies to determine the optimal tilt angle and to calculate the solar radiation methods for Antalya province [22-24], the number of district-based studies is negligible. Therefore, it is believed that this study will contribute to the case study of the region just in case an installation of large-scale solar systems in the region.

Several studies have been focused on the calculation of the Levelized Cost of Energy (*LCOE*) of solar systems. It was seen that the financial parameters have the biggest impact on the *LCOE*, apart from the location [25], and it was shown that both device and field lifetimes are critical for achieving a low *LCOE* for a solar power station [26]. The energy gain and *LCOE* resulting from fixed, single, and dual-axis solar trackers had been compared [27]. The impact of the installation parameters of fixed-tilt and single-axis systems on the energy yield, the *LCOE*, and the bifacial gain had been investigated [28]. In the current study, *LCOE*-based solar installation and solar energy costs have been investigated and evaluated for approximate cost analysis of solar systems to be installed in Antalya province.

3 MATERIALS AND METHODS

Optimal tilt angle determination models are based on using various optimization techniques to reach maximum radiation fall on a tilted solar surface. The used model in this study provides a more advanced approach that includes other factors such as atmospheric scattering, the impact of air pollution, climatic conditions, as well as direct sunlight.

3.1 Basics of Solar Energy and Numerical Analysis

The monthly average daily solar radiation values falling on horizontal surfaces are required to measure the monthly average daily solar radiation collected by the tilted surfaces in solar systems. A basic method is presented by Liu and Jordan [29] to estimate the monthly average daily radiation falling on tilted south-facing solar surfaces. The declination angle is measured from the sun north or south of the earth's equator. The tilt angle of the surface is the angle between the earth of the solar surface and the horizon. In relation to the earth's orbit around the sun, the axis of the earth is inclined at 23.45 degrees. Solar declination is affected by the time of year and can be obtained by using Eq. (1) [30, 31].

$$\delta = 23.45 \cdot \sin\left(2\pi \frac{284+n}{365}\right), \tag{1}$$

where δ is the declination and n is the day of the year.

Solar time is a method of determining the passage of time based on the sun's position in the sky. Sunset has occurred when the cosine of the zenith angle is 0, this is when the sun is at the horizon and is obtained by using Eq. (2) [31].

$$\omega = \cos^{-1}(-\tan\phi \cdot \tan\delta), \tag{2}$$

where ω is the solar time.

Extraterrestrial radiation is the solar radiation that exists outside of the earth's atmosphere. Daily extraterrestrial radiation on a horizontal surface is given by Eq. (3) [29].

$$H_0 = \frac{24}{\pi} \cdot G_{sc}\left[1+0.033\cdot\cos\left(\frac{360\cdot n}{365}\right)\right]\cdot \cdot\left(\cos\phi\cdot\cos\delta\cdot\sin\omega+\frac{\pi\cdot\omega}{180}\cdot\sin\phi\cdot\sin\delta\right), \tag{3}$$

where H_0 is the daily extraterrestrial radiation falling on a horizontal surface, G_{sc} is the solar constant 1367 W/m^2, and ϕ is the latitude of the location.

Global solar radiation is broken down into two components: beam radiation emanates from the sun to the earth's surface without any scattering by the atmosphere, and diffuse radiation emanates from the rest of the sky and does not cast a shadow. The sum of the beam and diffuse radiation is expressed by Eq. (4).

$$H = H_b + H_d, \tag{4}$$

where H is the global solar radiation, H_d and H_b are diffuse and beam radiation components of the average daily solar radiation.

Monthly average daily diffuse radiation is calculated using correlation formula given in Eq. (5) [32] which gives the diffuse fraction as a function of the clearness index.

$$\frac{H_d}{H} = 1.391 - 3.560\cdot K_t + 4.189\cdot K_t^2 - 2.137\cdot K_t^3, \tag{5}$$

where K_t is the clearness index, which is basically the ratio of surface radiation to extraterrestrial radiation.

The isotropic model is preferred to obtain monthly average daily solar radiation falling on a tilted surface and is expressed by Eq. (6) [26, 31].

$$H_t = H_b R_b + H_d \cdot\left(\frac{1+\cos\beta}{2}\right) + H\cdot\rho\cdot\left(\frac{1-\cos\beta}{2}\right), \tag{6}$$

where H_t is the calculation of hourly radiation in the plane of the solar surface, H_d and H_b are diffuse and beam radiation components of the average daily solar radiation, R_b is the beam radiation tilt factor, and β is the tilt angle.

The beam radiation tilt factor is affected by atmospheric transmittance which includes water vapor, cloudiness, and particulate concentration. It is expressed with its component by Eqs. (7) and (8) [29].

$$R_b = \frac{\cos(\phi-\beta)\cdot\cos\delta\cdot\sin\omega' + \left(\frac{\pi}{180}\right)\cdot\omega'\cdot\sin(\phi-\beta)\cdot\sin\delta}{\cos\phi\cdot\cos\delta\cdot\sin\omega + \left(\frac{\pi}{180}\right)\cdot\omega\cdot\sin\phi\cdot\sin\delta}, \tag{7}$$

$$\omega' = \min\begin{cases}\omega = \cos^{-1}(-\tan\phi\cdot\tan\delta)\cdot \\ \cdot\cos^{-1}\left[-\tan(\phi-\beta)\cdot\tan\delta\right]\end{cases} \tag{8}$$

where "min" expresses the smaller of the two items on the right side.

3.2 Case Study Region

The case study region is Antalya province with the scope of this study. Knowledge of total solar radiation distribution is needed for the correct structure and size of solar systems. The annual average global solar radiation distribution (between 2004 and 2018) provided by the Turkish State Meteorological Service [33] for the region is shown in Fig. 1. As depicted in the figure, Antalya has a high solar radiation

potential. Also, the geographical locations of Antalya districts are presented in Tab. 1, the districts of research interest in this study are established at altitudes very close to sea level except for Manavgat.

Table 1 Geographical location of Antalya districts

Districts	Latitude (°N)	Longitude (°N)	Elevation (°)
Alanya	36.6	32	86
Kaş	36.2	29.6	17
Manavgat	36.8	31.5	272
Muratpaşa	36.9	30.7	45

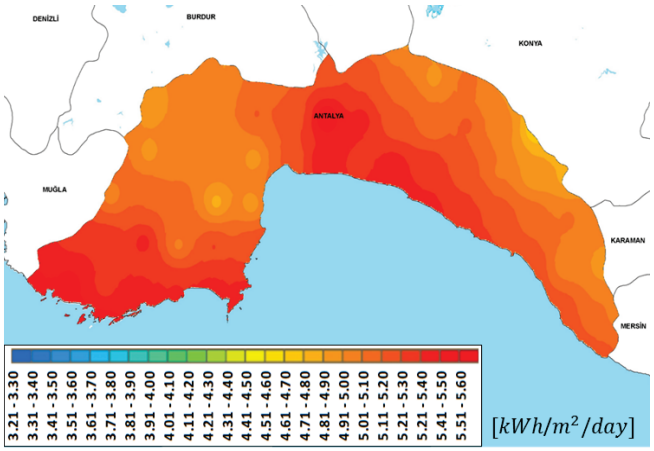

Figure 1 Annual average global solar radiation distribution of Antalya Province

3.3 Used Data and Proposed Calculation Model

Various estimation methods and simulation programs are used by researchers to determine the optimal tilt angle and obtain maximal benefit from solar radiation. In this way, it has become easier to make realistic analyses. RETScreen is a clean energy management and simulation software developed by the Minister of Natural Resources Canada that calculates using satellite and ground station interactive meteorological data provided by the National Aeronautics and Space Administration (NASA) [34]. It simulates the optimal hourly, daily, monthly, and annual solar radiation values in different options, depending on the desired geographical region and the clearness index [35]. So, within the scope of the study, the RETScreen model is preferred to compute the amount of radiation falling on the tilted surfaces and to find optimal angles of the tilted surfaces for fixed and solar tracking systems.

3.4 Description of the Calculation Algorithm

To measure radiation falling on a tilted solar surface, total radiation is initially measured falling on a horizontal surface, and collective data of the horizontal surface is used to calculate radiation falling on a tilted surface. Because the amount of radiation can be varied according to the region, the daily average values of solar radiation falling on a horizontal surface is the most important parameter to optimize the tilt angles of the solar surfaces.

The total solar radiation falling on a tilted surface is possible to calculate hourly and daily by using well-known equations [29, 31]. The RETScreen calculation model [36] is applied based on Duffie and Beckman's methods, and it is used an approach similar to the proposed algorithm by Klein and Theilacker [37]. On the other hand, the algorithm has been extended to solar tracking systems by using well-known solar geometry equations to investigate maximal solar radiation [38]. Solar geometry for fixed and tracking surfaces with oriented south are illustrated in Fig. 2. The fixed-axis solar surface, one-axis tracking solar surface, and two-axis tracking solar surface are illustrated in Fig. 2a, Fig. 2b, and Fig. 2c respectively.

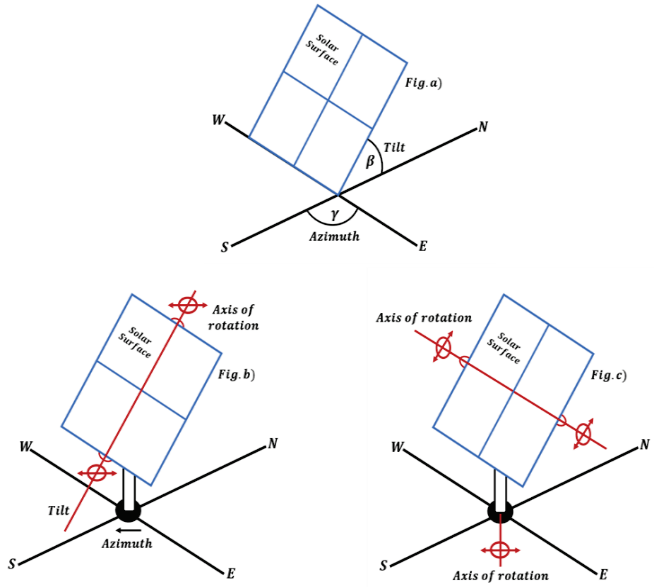

Figure 2 Solar geometry for fixed and tracking solar surfaces
a) Fixed-axis, b) One-axis tracking, c) Two-axis tracking.

The independent variables of the calculation algorithms are the latitude, longitude, and elevation of the analyzed geographic region. Total radiation values are obtained daily and hourly for fixed and tracking systems. The calculation is performed with one-hour step covering 365 days of the year. Calculations start with hourly total radiation falling on a horizontal surface. A mathematical method is then used to transpose these values onto a tilted surface. The optimal tilt angle is determined by looking for values at which the total radiation falling on the solar surface is maximum for a certain day or a certain period.

The calculation algorithm shown in Fig. 3 for the solar radiation collected by the tilted surfaces can be broken down into 3 simple phases. Phase 1 is the calculation of the hourly total radiation (beam and diffuse) falling on a horizontal surface for all hours of an "average day" as the monthly average. The concept of the suggested average days for months and declination values are presented in Tab. 2. Phase 2 is the calculation of the hourly values of total solar radiation falling on the fixed or tracking surfaces for all hours of the day. Phase 3 is the calculation of the hourly tilted values to find the average daily radiation falling on the surfaces.

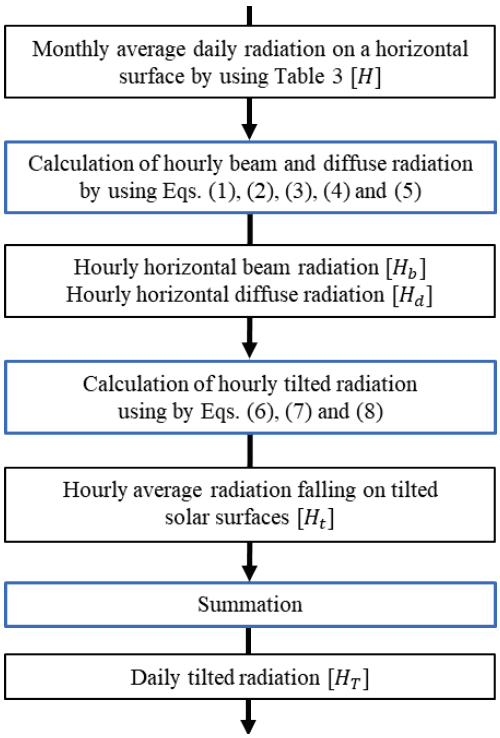

Figure 3 Flowchart of the calculation algorithm [kWh/m²]

Table 2 Suggested AVG days for months and values of n by months [24-26]

Month	Day of the Year	Date	Decl. δ
Jan	17	17 January	–20.9
Feb	47	16 February	–13.0
Mar	75	16 March	–2.4
Apr	105	15 April	9.4
May	135	15 May	18.8
Jun	162	11 June	23.1
Jul	198	17 July	21.2
Aug	228	16 August	13.5
Sep	258	15 September	2.2
Oct	288	15 October	–9.6
Nov	318	14 November	–18.9
Dec	334	10 December	–23.0

4 SOLAR SYSTEM COST ANALYSIS BASED ON LCOE

The cost of solar energy continues to decrease thanks to increased module efficiency as well as lowered hardware and inverter costs in recent years despite the impact of the global pandemic and the disruptions caused by the spread of the COVID-19 virus [39]. A significant portion of the cost declines over the past decade has been sourced from an 85% cost decline in solar module price [40]. *LCOE* [41] is a useful metric for detailed cost comparison, assessing economic potential including the payback period, and the most important criteria for the most large-scale solar systems. Solar engineers and investors aim to create solar systems to maximize financial returns by minimizing the *LCOE*.

4.1 Numerical Background of LCOE

The economic potential of solar systems is determined in this study via an *LCOE*, which describes how much it would cost to produce a unit of energy taking generalized assumptions about the costs of construction and operation of a typical solar system. It is expressed by Eq. (9) [42, 43].

$$LCOE = \frac{\sum_{t=1}^{n} \frac{I_t + M_t \cdot F_t}{(1+d)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+d)^t}}, \quad (9)$$

where *LCOE* is the average lifetime levelized cost of electricity generation, I_t is investment expenditures in the year t, M_t is operations and maintenance expenditures in the year t, F_t is fuel expenditures in the year if any, E_t is energy generation in the year t, d is the discount rate, and n is the lifetime of the solar system in years.

4.2 Solar Energy Cost

LCOE is the product of all of the lifetime costs associated with the construction and operation of the solar system divided by the energy produced during this lifetime. The value is ranged globally from under \$0.03/kWh to \$0.12/kWh. The *LCOE* in Türkiye almost halved between 2016 and 2021, reaching to a value of \$0.064/kWh [42]. For this reason, there is no doubt that the solar energy can be profitable in countries with high energy tariffs and high solar potential at the same time such as Türkiye.

4.3 Solar System Installation Cost

Multiple unique factors go into the cost of solar surfaces, and the cost varies depending on different regions of the world. According to Solar Energy Industries Association's (SEISA) average cost figures in 2021, utility-scale solar system installation costs are typically between \$0.89 to \$1.01/Wdc [44]. It is assumed that the land is already owned to build the solar system on. Based on the U.S. Department of Energy's National Renewable Energy Laboratory (NREL) [45], on average, complete solar system costs are \$2.65/Wdc for 7.2 kW residential, \$1.56/Wdc for 200kW commercial, \$1.03/Wdc for 10 MV fixed-tilt large-scale, and \$1.13/Wdc for 10 MV one-axis-tracking large-scale. These values represent the *LCOE* which is the average revenue per unit of energy generated that would be required to recover the costs of the solar systems over their life expectancy. The average cost of a solar system for the last 5-years is presented in Fig. 4, and the solar system cost for a complete installation is shown in Tab. 3 provided by the NREL [45].

Compared to single-axis trackers, the initial cost of dual-axis trackers is higher, and both trackers require extra space to avoid shadowing effects from one solar surface to the next, thus, space may not be utilized as effectively as with fixed panels. Oftentimes, solar trackers also require more maintenance. So, most solar engineers recommend buying additional solar surfaces instead of installing trackers. On the other hand, seasonal variations significantly affect the total energy provided by the solar surface. For a 1 kWp PV system, the additional energy produced from the single-axis and double-axis tracking systems was found to be 33% and 37 %

higher in comparison to the static systems [46]. Also, one-axis tracking systems are the best option in all countries, reducing *LCOE* by more than 20% when compared to two-axis tracking systems [47].

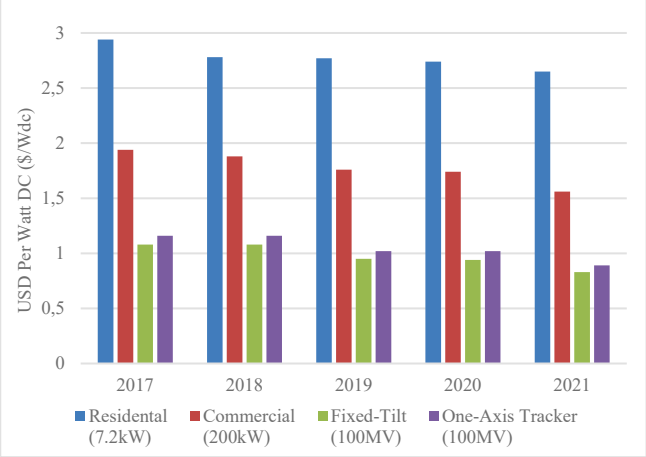

Figure 4 The average cost of a solar system for the last 5-years ($/Wdc)

Table 3 The average cost of a solar system for the year 2021 ($/Wdc)

Type	Capacity	Cost ($)	Type	Capacity	Cost ($)
Residential	7.5 kWdc	2.65	Fixed Tilt	10 MV	1.03
	9 kWdc	2.34		50 MW	0.91
	11 kWdc	2.14		100 MV	0.83
Commercial	200 kW	1.56	1-Axis Tracker	10 MV	1.13
	500 kW	1.46		50 MW	0.98
	1 MW	1.43		100 MV	0.89

4.4 Solar System Installation Cost Factors

The cost of solar system installation depends on location, energy needs, type of solar surfaces, inverter and equipment options, permits, inspection, tax credits, labor costs, etc. The cost factors are shown in Fig. 5 as percentage values. Balance of System (BOS) includes structural, electrical, and installation components. Through the BOS components, cost control, efficiency, and modernization of systems are realized. Operational costs include supply chain, general overheads, tax, maintenance requirements, etc.

4.5 Payback Period (Recovery of Investment)

A solar system's cost recovery period can vary depending on the used technology, system type, region, and the cost of electricity. Payback periods could vary depending on different countries, and different regions even within one country. This period compares with the average solar system lifetime of around 25-30 years [48]. The average solar system payback period is 7 to 12 years globally and most solar systems start generating a return on investment after 8-years [49-52]. Economic analysis and payback period (recovery of investment) calculation studies have been conducted for various regions of Türkiye. It is found that the average solar system payback period can vary depending on the region of the Türkiye [53-56]. The new incentives and tax breaks in Türkiye reduce average payback periods to under 7-years today and 2-years in 2030 [57, 58] for residential systems.

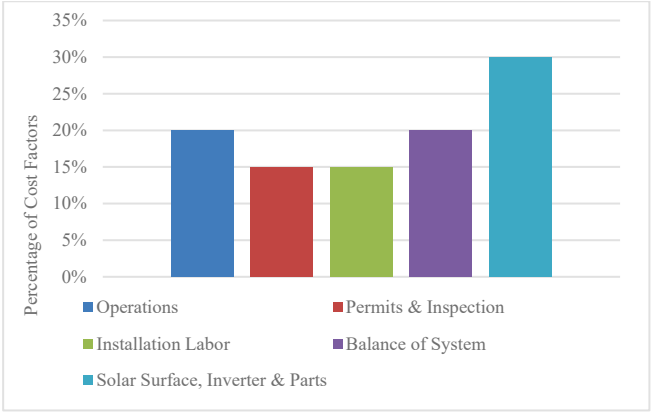

Figure 5 The average cost of a solar system for the last 5-years ($/Wdc)

5 CALCULATIONS AND RESULTS

In this section, first the proposed calculation model is applied to the Antalya province. Later, the discussions on *LCOE* and payback, and the discussions for applying the calculation model to large scope are presented respectively.

By using monthly average daily radiation values falling on a horizontal surface, climatic, and latitude data obtained from NASA for the districts of Antalya province, optimal tilt angles of the solar surfaces, and maximal solar radiation gain have been calculated for a specific period. Results are presented in tabular and graphical forms. By using the calculation method, the tilt angle value where the measured maximum radiation is determined as the optimum tilt angle. The surface azimuth angle is fixed to 0° for directly facing the equator. It can be used to calculate average solar radiation at any time of year for solar surfaces.

5.1 Solar Radiation Falling on Horizontal Surfaces

The monthly average daily radiation values falling on a horizontal surface for the Antalya districts are presented in Tab. 4. It is seen that from Tab.3, the Manavgat district has the best radiation efficiency considering the monthly and annual values. The second-best productive district is Kaş. The elevation of Manavgat is higher than the others. Since the most important solar parameter is horizontal radiation value, Manavgat has advantageous productivity compared to other districts.

5.2 Optimal Tilt Angle Results

Optimal tilt angles of the districts of Antalya province are calculated for solar systems, and the comparison of monthly optimal tilt angle values of the districts is shown in Fig. 4. Monthly optimal tilt angle values depending on the months are shown in the extreme points of the curves which represent the maximum values. It is understood from Fig. 4 that there is an optimal tilt angle for each month of the year when solar radiation is at its highest. Taking the calculated tilt angle values into account, solar radiation can be utilized to the maximum level.

Table 4 Monthly average daily radiation on horizontal surface (kWh/m²/d) [26]

Month	Alanya	Kaş	Manavgat	Muratpaşa
Jan	2.16	2.50	2.48	2.09
Feb	2.88	3.32	3.38	2.88
Mar	4.00	4.63	4.75	4.12
Apr	5.04	5.70	5.78	5.12
May	6.36	6.96	7.03	6.13
Jun	7.45	8.06	8.06	7.17
Jul	7.44	7.93	7.98	7.18
Aug	6.61	7.08	7.19	6.32
Sep	5.42	5.90	6.00	5.30
Oct	3.86	4.20	4.23	3.79
Nov	2.50	2.77	2.78	2.58
Dec	1.87	2.11	2.11	1.85
Annual	4.64	5.11	5.16	4.55

To find the optimal tilt angles of surfaces and total solar radiation collected by the tilted solar surface monthly, calculations are done for all tilt angles between 0° and 90°. For the districts of Antalya province, the monthly, seasonal, and annual optimal tilt angles and the monthly average daily solar radiation gain at these tilt angles are presented in Tab. 5. The differences in the amount of radiation gain as a result of the effect of the tilt angle can be seen in Tab. 4. It is seen that the optimal tilt angle values are determined between 0° (Jun) and 61° (Dec) throughout the year. The annual optimal tilt angle is determined to be between 28° and 30° for a solar surface that faces south throughout the year.

It is determined that the lowest optimal tilt angle is between 0° (Jun) and 2° (Jul), and the highest monthly average daily radiation values are observed during the same months. The optimal tilt angle then rises during the winter months and reaches 61° in December. The optimal tilt angles are determined for the winter season between 55°-57°, and the lowest monthly average daily radiation values are observed in December and January. The optimal tilt angles determined for the summer season are between 4°-5°.

As seen from the monthly tilt angles graph (see Fig. 6), the tilt angles reach their highest value in the winter season and go down to their lowest value in the summer season. While the highest optimal tilt angles of all districts are seen in December, the lowest optimal tilt angle value for all districts is in June. This is because Türkiye is located in the northern hemisphere, the sun rays in the summer are steep compared to the winter months. The optimal tilt angle values for Antalya districts decrease from January to June and increase again from June to December. The biggest reason for this decrease and increase in the optimal tilt angles during the year is that the declination angle (δ) increases until June and decreases after June. As the declination angle increases, the optimal tilt angle decreases or vice versa. The orientation (azimuth and tilt angles) of the solar surfaces can be adjusted when the supporting structure is designed accordingly.

In solar surfaces that do not have a solar tracking system, the tilt angles can be varied seasonal to benefit from solar radiation more efficiently. However, when the tilt angles of the surfaces are not possible to set monthly or seasonally, the tilt angles of the solar surfaces can be set annually.

Table 5 Opt. tilt angles (°) and monthly average daily radiation gains (kWh/m²/d)

Alanya District of Antalya Province						
Month	Monthly-Fixed		Seasonally-Fixed		Annually-Fixed	
	Tilt	Rad. Gain	Tilt	Rad. Gain	Tilt	Rad. Gain
Dec	59	3.05	55	3.04	28	2.70
Jan	57	3.41		3.41		3.06
Feb	48	3.84		3.81		3.67
Mar	34	4.60	19	4.47		4.57
Apr	19	5.26		5.26		5.22
May	6	6.39		6.30		6.12
Jun	0	7.45	5	7.44		6.89
Jul	2	7.45		7.45		7.00
Aug	15	6.79		6.7		6.68
Sep	31	6.10	43	6.0		6.09
Oct	46	5.10		5.1		4.90
Nov	56	3.87		3.79		3.51
Kaş District of Antalya Province						
Month	Monthly-Fixed		Seasonally-Fixed		Annually-Fixed	
	Tilt	Rad. Gain	Tilt	Rad. Gain	Tilt	Rad. Gain
Dec	60	3.59	56	3.59	29	3.17
Jan	59	4.15		4.15		3.70
Feb	49	4.58		4.55		4.36
Mar	36	5.43	21	5.28		5.40
Apr	20	5.98		5.98		5.93
May	5	6.99		6.85		6.65
Jun	0	8.06	4	8.05		7.37
Jul	2	7.94		7.94		7.39
Aug	16	7.28		7.14		7.14
Sep	32	6.70	44	6.59		6.69
Oct	47	5.65		5.64		5.43
Nov	57	4.41		4.31		3.99
Manavgat District of Antalya Province						
Month	Monthly-Fixed		Seasonally-Fixed		Annually-Fixed	
	Tilt	Rad. Gain	Tilt	Rad. Gain	Tilt	Rad. Gain
Dec	61	3.70	57	3.69	30	3.25
Jan	60	4.20		4.20		3.75
Feb	50	4.76		4.73		4.52
Mar	37	5.64	21	5.46		5.60
Apr	21	6.08		6.08		6.03
May	6	7.07		6.93		6.71
Jun	1	8.06	5	8.05		7.35
Jul	2	7.98		7.99		7.42
Aug	16	7.41		7.30		7.26
Sep	32	6.87	45	6.74		6.86
Oct	48	5.78		5.77		5.55
Nov	58	4.53		4.44		4.10
Muratpaşa District of Antalya Province						
Month	Monthly-Fixed		Seasonally-Fixed		Annually-Fixed	
	Tilt	Rad. Gain	Tilt	Rad. Gain	Tilt	Rad. Gain
Dec	59	3.04	55	3.03	29	2.71
Jan	57	3.29		3.29		2.98
Feb	48	3.86		3.84		3.7
Mar	35	4.77	20	4.65		4.75
Apr	20	5.36		5.36		5.31
May	6	6.16		6.06		5.88
Jun	0	7.17	5	7.16		6.62
Jul	2	7.19		7.19		6.73
Aug	15	6.49		6.41		6.37
Sep	31	5.97	44	5.86		5.96
Oct	46	5.02		5.01		4.83
Nov	57	4.09		4.01		3.71

5.3 Analyzing Optimal Tilts and Optimal Average Tilts

A comparison of the annual optimal tilt angle and the annual average optimal tilt angle is presented in Tab. 6. As can be seen in Tab. 6, by taking the average of the monthly and seasonally determined optimal tilt angles, the annual

average optimal tilt angle values have been found. There are 2°-2.5° deviations between the annual average optimal tilt angle values and the annual optimal tilt angle values of the districts of Antalya province.

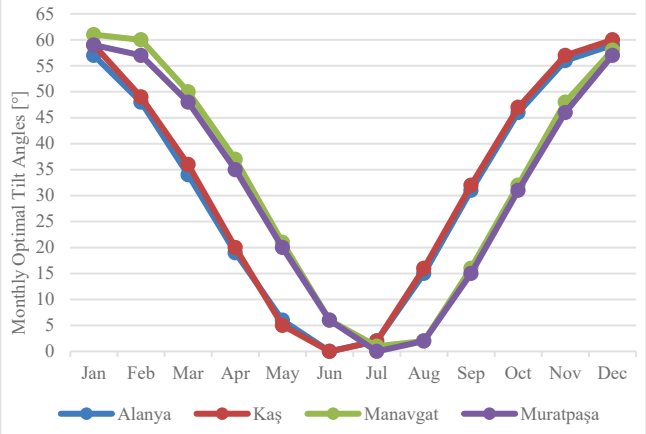

Figure 6 Monthly optimal tilt angle values obtained for districts of Antalya

This deviation is expected to increase further as move from the equator to the poles (especially at great latitudes) because the variations in the angle of incidence of the sun are greater or more frequent. This means the annual average optimal tilt angles do not represent the annual optimal tilt angles which is a separate concept. Optimal tilt degrees are reached when it is done over the maximum amount of radiation falling on the tilted surface, using the mathematical model that takes into account the solar climate conditions. So, calculations made with this model show that monthly and seasonal average tilt angles are not an optimal tilt angle determination, it is an approximate estimation of tilt angles. It has been determined that average angles deviate from optimal angles.

Table 6 Comparison of the annual opt. Tilt, and annual average opt. tilt (°)

Annual Optimal Tilts	Alanya	Kaş	Manavgat	Muratpaşa
Monthly AVG Opt. Tilt	31.08	31.92	32.67	31.33
Seasonally AVG Opt. Tilt	30.50	31.25	32	31
Fixed Annual Opt. Tilt	28	29	30	29

5.4 Solar Radiation Collected by the Fixed-Axis Surfaces

When the monthly average daily radiation values collected by solar surfaces with different tilt angles presented in Tab. 5 are analyzed comparatively. The monthly average daily radiation values are measured between 2.70 kWh/m^2 (Dec) and 7.42 kWh/m^2 (Jul) in case the solar radiation reaches the solar surface with the annual optimal angles range. In the winter season (Dec-Jan-Feb), the optimal tilt angle values are determined between 55° and 58°, the monthly average daily radiation values are measured between 3.04 kWh/m^2 and 4.76 kWh/m^2. In the spring season (Mar-Apr-May), the optimal tilt angle values are determined between 19° and 21°, the monthly average daily radiation values are measured between 4.60 kWh/m^2 and 7.07 kWh/m^2. In the summer season (Jun-Jul-Aug), the optimal tilt angle values are determined between 4° and 5°, the monthly average daily radiation values are measured between 6.49 kWh/m^2 and 8.06 kWh/m^2. In the autumn season (Sept-Oct-Nov), the optimal tilt angle values are determined between 43° and 45°, the monthly average daily radiation values are measured between 3.87 kWh/m^2 and 7.87 kWh/m^2.

5.5 Analysis of Solar Radiation Maximization Results

The monthly total solar radiation gain collected by the solar surfaces in case of using monthly, seasonal, and annual optimal tilt angles for Antalya districts are listed in Tab. 7. Calculations have been performed to maximize solar radiation falling on the solar surfaces regarding each combination of a tilt and azimuth angle. The results are presented for all months of the year, it returns the best combination of both geometry parameters for calculated periods in terms of finding optimal tilt angle and maximizing solar radiation accordingly. Also, it can be observed that the increase or decrease of the collected radiation for any values of azimuth and tilt of solar surface in the chosen period. So, one of the important outcomes in this study is the graphs and tables displaying the change in tilt angle in terms of increase or decrease and the amount of collected radiation. It is seen that from Tab. 6, the total monthly average radiation values are measured between 83.70 kWh/m^2 in December, and 230.02 kWh/m^2 in Jul in case of radiation reaches the solar surface with the optimal annual tilt angle. The conclusion to be drawn from the data in Tab. 6 is that solar radiation can be captured as a maximal level if the optimal tilt angle is set for each month. As a result, surfaces should be tilted at certain angles to maximize the benefits of solar radiation.

The annual total solar radiation collected by the solar surfaces for the Antalya districts is presented in Tab. 8. Manavgat district has the best radiation efficiency considering the annual fixed values in Tab 7. The maximal total annual average radiation values are measured in Manavgat as 2,194.66 kWh/m^2 for monthly, 2,173.28 kWh/m^2 for seasonal, 2,082.50 kWh/m^2 for annual respectively with applying the optimal tilt angles provided in this study. The high radiation rates of districts are contributed significantly to the gain of more radiation on fixed surfaces. It seems that the reason why Antalya province is preferred especially for the establishment of large-capacity solar systems is that it can be made a serious difference in energy generation.

5.6 Analyzing Radiation Gain for Tracking Systems

Solar tracking systems are effective tools to be used in solar systems where higher solar radiation efficiency is required. The average monthly total radiation on south-facing solar surfaces along the tilt angle gradient of 0° to 90° is calculated and presented in Tab. 9 for one-axis, and two-axis tracking surfaces of four districts of Antalya. It is understood that from Tab. 9, Manavgat and Kaş are the best productive districts for the radiation efficiency of the solar surfaces in case using tracking systems. The maximal total monthly radiation values are measured in Manavgat as 326.12

kWh/m^2 for one-axis, and 340.69 kWh/m^2 for two-axis respectively. In cases where it is not applicable to set the tilt angles of the surfaces, or if there is no solar tracking system, the monthly optimal tilt values presented in Fig. 4 can be used for districts of Antalya province.

Table 7 Total monthly radiation gain [kWh/m^2/d] in case of using opt. tilt angles (°)

Alanya District of Antalya Province			
Month	Monthly	Seasonally	Annually
Jan	105.71	105.71	94.86
Feb	107.52	106.68	102.76
Mar	142.60	138.57	141.67
Apr	157.80	157.80	156.60
May	198.09	195.30	189.72
Jun	223.50	223.20	206.70
Jul	230.95	230.95	217.00
Aug	210.49	207.70	207.08
Sep	183.00	180.00	182.70
Oct	158.10	158.10	151.90
Nov	116.10	113.70	105.30
Dec	94.55	94.24	83.70
Kaş District of Antalya Province			
Month	Monthly	Seasonally	Annually
Jan	128.65	128.65	114.70
Feb	128.24	127.40	122.08
Mar	168.33	163.68	167.40
Apr	179.40	179.40	177.90
May	216.69	212.35	206.15
Jun	241.80	241.50	221.10
Jul	246.14	246.14	229.09
Aug	225.68	221.34	221.34
Sep	201.00	197.70	200.70
Oct	175.15	174.84	168.33
Nov	132.30	129.30	119.70
Dec	111.29	111.29	98.27
Manavgat District of Antalya Province			
Month	Monthly	Seasonally	Annually
Jan	130.20	130.20	116.25
Feb	133.28	132.44	126.56
Mar	174.84	169.26	173.60
Apr	182.40	182.40	180.90
May	219.17	214.83	208.01
Jun	241.80	241.50	220.50
Jul	247.38	247.69	230.02
Aug	229.71	226.30	225.06
Sep	206.10	202.20	205.80
Oct	179.18	178.87	172.05
Nov	135.90	133.20	123.00
Dec	114.70	114.39	100.75
Muratpaşa District of Antalya Province			
Month	Monthly	Seasonally	Annually
Jan	101.99	101.99	92.38
Feb	108.08	107.52	103.60
Mar	147.87	144.15	147.25
Apr	160.80	160.80	159.30
May	190.96	187.86	182.28
Jun	215.10	214.80	198.60
Jul	222.89	222.89	208.63
Aug	201.19	198.71	197.47
Sep	179.10	175.80	178.80
Oct	155.62	155.31	149.73
Nov	122.70	120.30	111.30
Dec	94.24	93.93	84.01

Maximal radiation gains for fixed systems and tracking systems are presented in Tab. 10. It is calculated that optimally angled surfaces achieve between 8.23% (Alanya) and 10.63% (Manavgat) more solar radiation annually compared to surfaces that are not angled at all for the fixed surface. It is also calculated that one-axis tracking systems harvest between 28.72% (Muratpaşa) and 33.17% (Manavgat) higher solar radiation, and two-axis tracking systems harvest between 32.19% (Kaş) and 37.49% (Manavgat) higher solar radiation than the fixed-axis systems in districts of Antalya. Considering an expected 25-year lifetime for the solar systems, optimal tilting of the surfaces should be taken seriously in solar systems. It is highly advised to utilize a one-axis tracking system in solar systems. However, solar tracking systems are high-cost to operate and maintain and are not always feasible because of the lack of free space. If changing the tilt angles of the solar surface is not possible, the annual fixed optimal tilt angle values can be used for solar energy systems during the installation. In the light of the obtained results, it is calculated that if the tilt angle is changed every month in the Antalya districts, an increase in the radiation values falling on the solar surfaces can be achieved between 4.87% (Kaş) and 5.28% (Manavgat) compared to annual fixed tilt angle. It is also calculated that if seasonally setting it between 3.80% (Alanya) and 4.32% (Manavgat) radiation gain compared to an annual fixed system. Especially for large-scale solar systems, this difference will have a significant impact.

Table 8 Total annual radiation gains (kWh/m^2/d) in case of using opt. tilt angles (°)

Districts	Monthly	Seasonally	Annually
Alanya	1,928.41	1,911.95	1,839.99
Kaş	2,154.67	2,133.59	2,046.76
Manavgat	2,194.66	2,173.28	2,082.50
Muratpaşa	1,900.54	1,884.06	1,813.35

Table 9 Total avg. monthly radiation gain (kWh/m^2/d) for solar tracking systems

Month	Alanya		Kaş	
	One-Axis	Two-Axis	One-Axis	Two-Axis
Jan	114.70	122.14	141.05	150.97
Feb	122.36	125.44	148.68	152.60
Mar	175.15	175.15	214.21	214.52
Apr	191.10	192.30	223.80	225.30
May	249.86	257.61	280.55	290.16
Jun	281.10	294.90	310.80	327.30
Jul	298.22	310.31	323.64	340.38
Aug	285.51	289.54	313.10	317.75
Sep	237.90	237.90	266.40	266.40
Oct	197.16	200.88	222.27	225.99
Nov	128.40	135.90	147.90	156.60
Dec	100.44	107.88	119.66	128.96
Month	Manavgat		Muratpaşa	
	One-Axis	Two-Axis	One-Axis	Two-Axis
Jan	143.22	153.14	110.98	117.49
Feb	154.84	159.04	123.76	126.56
Mar	224.44	224.75	183.83	183.83
Apr	228.90	230.70	195.60	196.80
May	284.58	294.50	237.77	245.83
Jun	310.50	327.30	267.00	280.80
Jul	326.12	340.69	284.27	296.05
Aug	320.85	325.81	268.77	272.80
Sep	275.10	275.10	231.60	231.60
Oct	228.16	232.19	194.06	197.16
Nov	152.40	161.10	136.50	144.60
Dec	123.38	132.99	100.75	107.88

Tab. 11 presents the annual average solar radiation gain in the four investigated districts in case using the solar tracking systems. Manavgat district is the best productive district for the radiation efficiency of the solar surfaces. Total annual average radiation values are measured 2,772.49 kWh/m^2 for one-axis, 2,857.31 kWh/m^2 for two-axis respectively. It is also revealed that the second-best productive district is Kaş in terms of radiation efficiency. Compared annually, a considerable increase in radiation values is observed in the Antalya districts. For this reason, it is recommended to investors that Manavgat and Kaş districts can be preferred in the Antalya province.

Table 10 Radiation gains of fixed systems and tracking systems (%)

Districts of Antalya	Annual Fixed-Axis (%)	On-Axis Tracking (%)	Two-Axis Tracking (%)
Alanya	8.23	29.34	33.15
Kaş	9.62	32.19	36.09
Manavgat	10.63	33.17	37.49
Muratpaşa	9.03	28.72	32.59

Especially for large-capacity solar systems, a two-axis tracking system can be created a considerable impact and can contribute greatly to the business economy. However, two-axis systems are quite costly. In this context, to utilize a two-axis tracking system, cost and benefit analysis should be done first. It is strongly advised to utilize a one-axis tracking system in solar systems.

Table 11 Total avg. annual radiation gain (kWh/m^2/d) for solar tracking systems

District	Solar Tracker Type	Radiation Gain
Alanya	One-Axis	2,381.90
	Two-Axis	2,449.95
Kaş	One-Axis	2,712.06
	Two-Axis	2,796.93
Manavgat	One-Axis	2,772.49
	Two-Axis	2,857.31
Muratpaşa	One-Axis	2,334.89
	Two-Axis	2,401.40

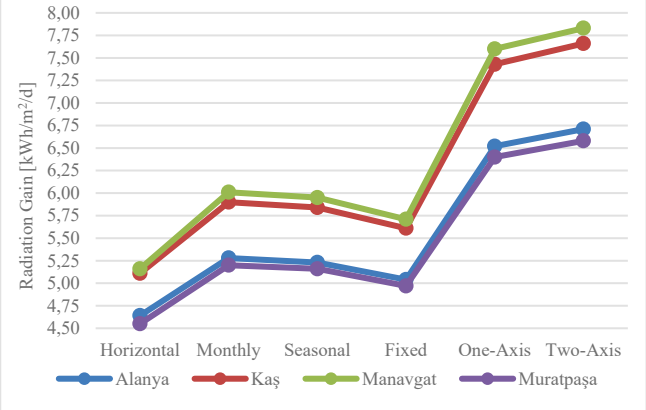

Figure 7 Annual average daily radiation falling on horizontal and tilted surfaces

Fig. 7 shows a comparison of solar radiation falling on fixed and tracking systems in the districts. The annual average daily radiation values are calculated by changing the tilt of the south-oriented surfaces with steps between 0°-90°, curve graphs are drawn depending on radiation gain from the fixed and tracking systems. It can be seen once again in Fig. 5 that tracking systems make a serious contribution to energy efficiency. So, to maximize radiation efficiency, solar surfaces need to be structured so that the tilt angle can be set effortlessly to use monthly or seasonal optimal tilt. At a minimum, surfaces should be set with an annual optimal tilt if the tracking system setup is not affordable financially.

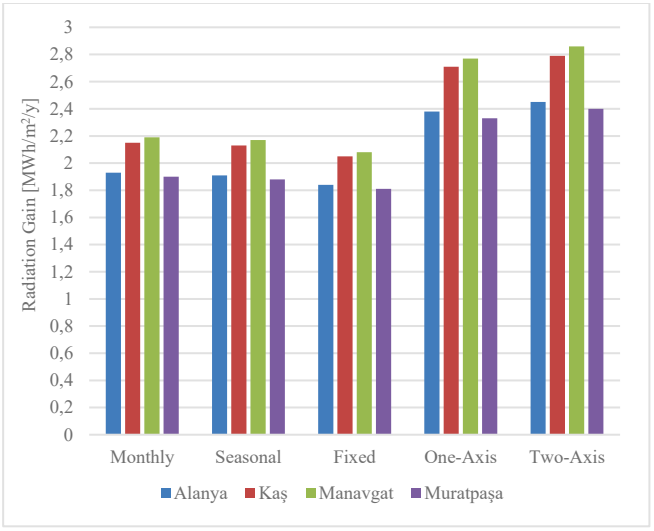

Figure 8 Total annual radiation for the districts of the Antalya province

Fig. 8 presents the annual radiation values of tracking systems and fixed systems for evaluating the existence of solar potential in Antalya districts. It is understood that from Fig. 8, the variation of collected solar radiation values from the tracking systems and fixed systems are the most essential parameter to the design and size of the large-capacity solar systems. It is also seen that tracking systems may significantly increase the collecting the radiation. Because of this, it is extremely important to use solar tracking systems to get high radiation efficiency.

5.7 Discussions on the Cost Analysis and Payback Period

As depicted Fig. 4, the cost of solar energy continues to decrease thanks to improved module efficiency as well as low hardware equipment costs in recent years. It is understood Tab. 3, large-scale solar systems are much cheaper to install and operate compared to residential and commercial solar systems. In other words, as the capacity of the solar system grows, the system installation costs decrease or change the type of solar system. Also, the cost increase in installing one-axis tracker structures in large-scale solar systems is less than expected. It is therefore highly suggested to install a one-axis tracker in such solar systems in terms of cost and economic efficiency. Fig. 4 shows that between the last 2 years, there were 3.28% ($0.09/Wdc), 10.34% ($0.18/Wdc), 10.83% ($0.11/Wdc), and 12.74% ($0.13/Wdc) globally reductions in the residential, commercial, large-scale fixed tilt and one-axis solar system cost respectively. The latest statistical data show that the solar energy in Türkiye cost is almost halved last 5-years. Hence, there is no doubt solar energy to support the economy in countries with high energy tariffs and at the same time high

solar potential such as Türkiye. It is also seen that the average solar system payback period is 7 to 12 years globally and most solar systems start generating a return on investment after 8-years comparing the 25 years lifespan of the system. The new incentives and tax breaks in Türkiye are reduced average payback periods to under 7-years. Due to the decrease in setup costs in the future, it is anticipated that the payback period will be lot less than today's payback periods.

5.8 Discussions on the Proposed Calculation Model

Because tilting and tracking are significant effects to increase incident solar radiation at all latitudes, the proposed model can be implemented in any location of interest to obtain specific estimates with a low computational cost. The proposed model can be used for evaluating the solar potential of a certain location before establishing a solar system and can be also easily applied by researchers and technicians in the field to avoid energy yield losses and unnecessarily high *LCOE*. In addition, different desired periods can be obtained such as daily, weekly, monthly, seasonally, and yearly optimal tilt values or radiation values for solar systems by using the data set for each location of interest in Türkiye or the world. The model can be extended to other rural regions in developing countries.

6 CONCLUSIONS

This study contributes in-depth to determining the optimal tilt angle of the solar surfaces and measuring total solar radiation falling on the tilted surface monthly, seasonal, and annually in Antalya districts within the proposed calculation model. The study also highly contributes to the estimation of radiation values collected by the surfaces in case using solar tracking systems for evaluating the existence of solar potential in Antalya districts.

The average daily radiation values are calculated using the proposed model by changing the tilt of the south-oriented surface with steps between 0° and 90°. It is observed that the optimal tilt angles during the year are varied between 0° and 61°. The annual optimal tilt angle is determined to be between 28° and 30° for a south-facing solar surface throughout the year. So, it has been determined that there is a ±1 or ±2 tilt angle difference between the four districts.

The monthly average daily radiation values are measured between 2.70 kWh/m^2 and 7.42 kWh/m^2 in case of radiation reaches the solar surface with the optimal annual tilt angle in the districts. The maximal total annual average radiation values are measured 2,194.66 kWh/m^2 for monthly, 2,173.28 kWh/m^2 for seasonal, 2,082.50 kWh/m^2 for annual respectively with applying the optimal tilt angles. The maximal total monthly radiation values are measured 326.12 kWh/m^2 for the one-axis, and 340.69 kWh/m^2 for the two-axis respectively. It is calculated that optimally angled surfaces achieve between 8.23% and 10.63% more solar radiation annually compared to surfaces that are not angled at all for the fixed surface. It is also calculated that one-axis tracking systems harvest between 28.72% and 33.17% higher solar radiation, two-axis tracking systems harvest between 32.19% and 37.49% higher solar radiation than the fixed-axis systems in districts of Antalya.

For the districts of Antalya, it is calculated that the monthly optimal tilt setting contributes between 4.87 and 5.28% radiation gain compared to an annual fixed system. It is also calculated that a seasonally setting contributes between 3.80 and 4.32% radiation gain compared to an annual fixed system.

These results demonstrate that monthly, seasonally, and annual positioning of the solar surfaces at the optimal tilt angles provides significant radiation efficiency. It is found that, under the same conditions, the tracking systems harvest great radiation efficiency compared to the fixed systems.

It is understood that the period, latitude, climatic characteristics, and geographical location are the most important parameters affecting the optimal tilt angle and radiation efficiency. It is also seen that Antalya has a perfect location for the installation of solar systems. The proposed calculation method can be applied to specific locations in Turkiye where the importance of solar systems is constantly increasing. It is thought that this study can help solar engineers and designers to improve the efficiency of solar surfaces, properly set optimal tilt angles, and choose the right methodology for installing solar systems in the districts of Antalya province.

When the findings of this study are compared to those of other studies in the literature, it is discovered that as consistent with the findings of similar studies. This study shows the importance of accurate tilt angle and orientation. It is thought that the study can contribute to the solar data literature of Antalya province. The proposed calculation model can be implemented any location in Türkiye and the world.

Recent research studies show that the solar energy cost and solar system installation cost continued to decrease thanks to increased panel efficiency and decreased hardware costs in globally. It is believed that *LCOE* based analysis presented in this study can guide engineers and investors to create solar systems and maximize financial returns by minimizing the costs in Antalya province. It is expected that solar energy will support the economy in countries with high energy tariffs and at the same time, high solar potential such as Türkiye since the solar energy cost is almost halved last 5-years. Because of the global reduction in large-scale one-axis solar system costs for the last 2-years 12.74%, it is highly recommended to install one-axis tracker systems in terms of not only economic potential but also energy efficiency.

It is also shown that in Türkiye, most solar systems start generating a return on investment after 8-years comparing the 25 years lifespan, the new incentives, tax breaks, existing solar potential, and continued declines in installation costs reduced average payback periods to under 7-years today.

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Authors' contacts:

Batur Alp Akgül, PhD Student
(Corresponding author)
Institute of Sciences, Hasan Kalyoncu University,
On the Airport Road 8. km. Şahinbey, Gaziantep, Türkiye
baturalpakgul@gmail.com

Fatih Alisinanoğlu, PhD Student
Institute of Sciences, Hasan Kalyoncu University,
On the Airport Road 8. km. Şahinbey, Gaziantep, Türkiye
fatih.alisinanoglu@hku.edu.tr

Muhammet Fatih Hasoğlu, PhD, Full Professor
Institute of Sciences, Hasan Kalyoncu University,
On the Airport Road 8. km. Şahinbey, Gaziantep, Türkiye
mfatih.hasoglu@hku.edu.tr

Mustafa Sadettin Özyazıcı, PhD, Full Professor
Institute of Sciences, Hasan Kalyoncu University,
On the Airport Road 8. km. Şahinbey, Gaziantep, Türkiye
msadettin.ozyazici@hku.edu.tr

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Designing a Model of Student Support in e-Learning Using Qualitative Content Analysis and Analytic Hierarchy Process

Ahmad Parizad, Aeen Mohammadi*, Rita Mojtahedzadeh, Mandana Shirazi

Abstract: Student support services, especially for students who study virtually, increase satisfaction, attract new students, complete the course, and improve overall student performance. Given the importance of student support in e-learning and the fact that student support models should be specific to the culture and economic conditions and technology of their context, the present study set to design a native model of student support in e-learning for post-graduate students. To conduct the research, first a systematic search was performed to extract the existing models of student support. Through forming an expert panel and rating the models, more compatible models with the context of Iran were selected. The interview questions were then extracted from the concepts of the models who scored the most in the expert panel session. In relation to the examples of student support, interviews were conducted with 22 university teachers, education officials, and post-graduate students studying in educational branches leading to a virtual degree of medical sciences. Using content analysis of codes, sub-categories and the resulting categories were extracted from the interviews. Finally, in the expert panel session, using the (analytic hierarchy process) AHP, the categories were prioritized and the model was designed. After analyzing the content of the interviews, four main categories, namely teaching and learning, interactions and communications, empowerment, and structural support were extracted and the final model of student support was designed using the opinions of e-learning instructors. Despite relatively similar similarities between the native model of student support for e-learning students and the existing models, this model, which is designed based on the needs of students and faculty and e-learning officials, places more emphasis on teaching, learning, interactions, and communications.

Keywords: e-Learning; Student Support; Student Support Models; Qualitative Content Analysis

1 INTRODUCTION

Student support is a general term used for a wide range of services and institutions to help students achieve learning goals and achieve knowledge, attitude, and skills [1]. To have effective e-learning, the necessary support must be provided to the student; otherwise, e-learning will fail [2]. E-learning support services include a set of human and non-human resources to guide and facilitate the training course. These resources can include library facilities, media types, software programs, social guides, or include a variety of socioeconomic parameters such as financial aid, self-confidence, and capacities to adapt to their plans and responsibilities in the family and community [3]. In e-learning, the student and the teacher are physically separated. This separation affects the teaching and learning of teachers and students and leads to reduced motivation, reduced student engagement with courses, and their dropout [4].

In addition, some learners feel lonely in e-learning. Also, some students who attend these classes drop out of school due to lack of self-management skills and lack of motivation and sense of belonging to their institution [5].

Student support services lead to student satisfaction, and student satisfaction with e-learning leads to attraction of new students and persistence of current students, improving the overall performance of students, and increasing their progress and employability in the future [6]. Grigori (2018) indicated that students are more satisfied with courses that have a higher level of student support, and the more the amount of interaction between students, content, and interaction among students themselves, the more likely the students complete the course [7]. Lack of student support system is a limiting factor in the development of e-learning [8]. Therefore, e-learning institutions should provide effective and useful student support services to meet the special needs of e-learning students and improve and enhance their learning experiences [9].

King Stone et al. argued that higher education institutions and universities should change their cultural approach to focus on students' learning needs since culture plays a central role in the provision of support services, and in fact, universities and their support systems should focus on the student and his needs [10]. To achieve this goal, educational institutions must consider their own context, culture, and assumptions to base their actions in this category. How educational institutions and universities provide support for students will ultimately lead to the viability of the chosen path [11]. It is very important that these systems (support services) actually seek to provide what students really need and are interested in Nichols [12]. Student support should be provided in a way that is usable and meaningful to him [13]. Student support services are highly dependent on the structure of the community, the potential of the community, and the facilities and needs of the university, but many aspects of student support systems are common to many universities. Therefore, inventory models that are more consistent with the educational context of another community can be used [14]. Studies show that many factors affect the provision of student support, so providers of student support services should consider various factors involved in the provision of student support in different universities and, accordingly, design the necessary support mechanism that is appropriate for their environment [15].

Considering the importance of student support in e-learning and the important role of student support systems in e-learning and the need to design a student support system in accordance with the needs of e-learning students in Iran, this study aimed to design a native model to support post-graduate students in e-learning.

2 MATERIALS AND METHOD

First, to find models of student support in e-learning, extensive searches were made in PubMed, ERIC, ScienceDirect, Ovid, Google Scholar, ISI, and Scopus databases from 2000 so far using the following formula.

TITLE-ABS-KEY(("student support" OR "learner support" OR "supporting student" OR " support services" OR support system OR "delighted student" OR "delighted learner") AND ("e-learning" OR "open learning" OR "electronic learning" OR "distance learning" OR "online learning" OR "mobile learning" OR "E-learning" OR "distance education" OR "open university" OR "distributed learning" OR "Open and distance learning" OR "M-learning") AND ("post graduate " OR "higher education" OR "University students")).

2.1 Inclusion and Exclusion Criteria

Based on the search strategy, studies conducted since 2000 were included in the study. Duplicate and unrelated articles were excluded.

2.2 Data Extraction

Data were collected independently based on a standard protocol by two researchers. Disagreements between the two were resolved through negotiation between the two researchers, and if no agreement was reached, the review would be done by a third party. The extracted data included the name of the first author, year of publication, name of the country, type of study, and findings related to the designed model.

Then, in the expert panel formed with the presence of experts and instructors of e-learning, the extracted models were explained, and to find more complete models and in accordance with the context of the country, each model was scored using the Brath Waith checklist. This checklist evaluates five areas: content comprehensiveness, conceptual clarity, logical coherence, level of abstraction, and applicability. Models that received the highest score in the expert group were selected from the existing models extracted from the systematic search. The concepts in the approved models in the expert panel were also used in designing the interview questions, focusing on the purpose of the study.

The researcher used purposive sampling. The study population consisted of post-graduate students of the e-learning course leading to a scientific degree (Department of Medical Sciences), instructors (i.e. the instructors of the mentioned courses, including faculty and non-faculty members), and education officials. The interview time was pre-arranged with the participants. Before starting the interview, the purpose of the research, the reason for recording the interview, voluntary participation, and confidentiality of information and the identity of the interviewees were explained; the participants were asked for their permission to record their audio. To observe the maximum variation, it was tried to select samples from students, teachers, and education officials with different economic, social, and demographic characteristics (such as age, marital status, being native, nonnative, etc.).

The research environment involved faculties and centers where students and teachers of virtual majors in medical sciences universities of Tehran, Iran, Shahid Beheshti, Shiraz, and the virtual university participated. After the initial agreement of the participants, the interview was conducted in the faculty, workplace, or any other environment they were interested in Sampling was continued until theoretical saturation of the data.

All these universities, in addition to in-person majors that are not considered in this study, have distanc e-learning majors for post-graduate. They are among the main and leading universities in e-learningin Iran. These universities use LMS for educating; most classes are held asynchronously, and classes are rarely held synchronously. Final exams in most of these universities are held face-to-face with the exception of the virtual university. At the end of the course, students will be offered a distance-learning degree.

At the beginning of the interview, the participants were asked to give a brief introduction, followed by questions about the participant's demographic status.Then, using the questions extracted from the expert panel session, semi-structured interviewe was performed for the participants, and research on the participants' views on various dimensions of student support in e-learning continued, guided by the interviewees. The discussion went on until the interviewer made sure that the interviewee understood the concepts well. The researcher tried to explain the participants' answers to each of the interview questions using follow-up questions and sentences such as can you explain more? or when you say what do you mean?

To analyze and interpret the data, qualitative content analysis method and inductive approach were used. The unit of analysis was the total number of interviews, which were reviewed and re-read several times after typing the recorded interviews. Accordingly, meaning units were identified as sentences or paragraphs from the statements and texts of the interview, and each keyword or sentence was given a code. At this stage, the primary codes were extracted from them, and then similar codes were placed in groups next to each other; thus, primary categories were formed. Then, by continuous comparison, similar sub-categories were merged, and finally the main categories and themes were abstracted. The analysis process continued continuously with the addition of each interview, and the codes and categories were modified.

Then, with the formation of an expert panel in which e-learning specialists were present, the AHP method was used to determine the priority areas of the student support model in e-learning. In this method, the student support domains extracted from the content analysis were compared in pairs, and the members of the expert panel were asked to determine the preference of each domain over the other. After determining the priorities of the domains from the point of view of the panel members, the final model of student

support in e-learning was designed for post-graduate students according to the priorities of the domains.

3 RESULTS

In the first step, which was a systematic review to find existing student support models, a total of 1448 articles were found. The articles were transferred to an endnote document, leaving 733 articles after deleting duplicates. After reviewing the articles and studying the titles and abstracts, 116 articles related to the topic of student support were found. Then, among these 116 articles, studying the text of the articles, students' support models in e-learning were searched, and six articles were detected in which student support models in e-learning were explained. These articles were then thoroughly studied and reviewed and the extracted dates were reported in Tab. 1.

Table 1 Student support models according to systematic search

Model categorization	Method	Model name	Country	Author and year	Results
Models based on different domains	Case Study	Mac Tage	Germany	Mac Tage [22] (2004)	• Help students to improve their research, writing, time management skills, and student support to complete their dissertations on time • Emphasis on the relationship between support methods and students' needs • Mere emphasis on cognitive domains • More emphasis on producers and education officials • Focus on the academic aspect
	Conceptual	Simpson	England	Simpson [2] (2013)	• Cognitive domain (promoting students' learning and cognitive skills) • Organizational area (helping to manage students' courses) • Emotional domain (helping the student to face the emotional domain of their learning, which includes helping the student to improve their learning motivation, enhance the student's confidence as a learner, and help the student to manage his stress, especially exam stress.
	Conceptual	Atkins	England	Atkins [24] (2008)	• Existence of a comprehensive student support approach • Change in the approach from university- centered to student-centered and participatory approach • Reflective support (strengthening student motivation) • Cognitive support • Emotional support (supporting students about how they feel about learning) • Systematic support
	Content analysis	Jung	South Korea	Jung [16] (2014)	• Providing a five-dimensional model of student support in e-learning students • Adding gender category to previous models based on the context of East Asian countries
	Content analysis	Mohammadimehr	Iran	Mohammadimehr [8] (2021)	• Providing a seven-dimensional model of student support in e-learning students. In addition to student support, professors and staff need to be supported.
Model based on education stages	Conceptual	Lap	America	Floyd [19] (2004)	• Learner perception phase: defining goals and assessing students' readiness • Learner assessment interventions: Student support for personal development and learning • Learner support: Helping the student to improve their skills • Learner transfer: Providing job selection consulting services • Measurement: Assessment of the effectiveness of the program

Table 2 Demographic characteristics of the participants

Variables		No. (%)
Gender	Female	6 (28%)
	Male	16 (72%)
Age	40≤	11 (50%)
	41-49	3 (14%)
	50≥	8 (36%)
Student		12 (54%)
Instructor		4 (18%)
Instructor and the education officer		6 (27%)

In the next stage, at the end of the expert panel session, two models scored higher than the existing models (Jung model and Lap model) and the participants unanimously agreed that these two models are more in line with the culture and conditions of Iranian society than the other models. In addition, are more complete. Then the interview questions are extracted from the content of these two models. The questions extracted were as follows: How familiar are you with the term student support and student support systems?

What is the role of university instructors, the faculty, and the education system in student support? What are student support needs at each stage of study? What are other examples of student support in your idea?

Then, 22: (twelve students), (four university instructors), and (six virtual education officials) were interviewed using questions approved at the expert panel meeting (Tab. 2).

From all interviews, 238 initial codes, 15 subcategories, and four main categories were extracted. The four categories described included "interaction and communication", "learning/ teaching", "empowerment" and "structural support".

3.1 Main Category/Teaching, Learning

Learning/teaching means learning supportive needs that are felt for the student to learn better in the field of knowledge (Tab. 3).

The teaching-learning category consisted of five sub-categories: "diversity of approaches and educational contexts", "support for student learning", "support by the teacher", "monitoring the student's academic status", and "accurate and transparent assessment of the student."

Table 3 Main themes and subthemes related to the student support in e-learning

Theme	Subtheme	Similar codes
Teaching/learning		
	Monitoring the student's educational status	• Monitoring student activity in the LMS • Following up students with low activity • Planning to manage students' study time • Monitoring thesis progress
	Support by the instructor	• Guiding the dissertation process by the professor, from the title selection to the final defense • Academic counseling and guidance by the instructor • Facilitating learning through appropriate interaction
	Correct and transparent student assessment	• Reliable and valid assessment • Variety in student assessment methods • Informing the evaluations method
	Approach variety and educational contexts	• Holding synchronous and asynchronous classes • Holding face-to-face sessions if needed • Justifying students for the importance of face-to-face sessions of the program
	Supporting student learning	• Lesson plan and study guide • The teacher's attention to student learning • Paying attention to students' learning style • Proper schedule for presenting teaching content • Increasing learning motivation through providing lessons and practical content • Instructor flexibility in educational affairs • Appropriate and timely feedback on assignments and learning activities • Providing learning activities tailored to the level of competence • Proportion between lesson content and learning activities • Using the social media platform for student learning
Interactions and communications	Communication with the instructor	• Superficial awareness about the instructor • Quick student access to the instructor • Easy student access to the instructor • Proportionate number of students to instructors • Appropriate emotional connection between the instructor and student • Need to meet the instructor in person • Creating an intimate connection in virtual educational spaces • Proper interaction in synchronous classes
	Communication with peers	• Ability to communicate with peers • Forming small groups of peers for learning
	Communication with graduates	• Possibility of communicating with higher year students • Formation of alumni associations • Holding training courses for graduates • Holding a graduation party
Empowerment	Instructor empowerment	• Empowering IT instructors • Empowering instructors to teach in the virtual space • Taking advantage of instructors specialized in virtual education
	Student empowerment for e-learning	• Empowering students to manage personal and academic affairs • Empowering students to acquire metacognitive and self-regulatory skills
Structural support	Attention to student affairs	
	Appropriate organizational support in the field of education	• Holding an introductory and briefing session upon arrival • Communicating sincerely with education experts

		• Assigning capable and responsive experts in virtual education • Full-time expert support • Transparent informing of educational affairs • Accountability of the education sector to the student • Group flexibility towards the student • Presence of an academic consultant • Clarity of the teaching and learning process
	Material and spiritual support	• Students' awareness about the future career of the academic discipline • Increasing learning motivation by recognizing the position of the discipline • Graduate job placement system • E-learning degree accreditation • Financial support system • Establishing similar support as for face-to-face course students such as food stamps, loans, etc. • Special privileges for top students
	Student evaluation of the instructor	
	Suitable infrastructure for e-learning	• transparent system of student evaluation of the instructor • Attention to the student evaluation results about the instructor • Attention of educational administrators to students' opinions • Curriculum revision for virtual presentation • Need to provide suitable infrastructure for synchronous and asynchronous classes

1) Variety of approaches and educational contexts

One of the participants mentioned in the interview that the inclusion of in-person sessions in the e-learning program will cause the student to interact more with the teacher and will remove ambiguities and questions related to the lesson, and ultimately lead to better learning of the lessons.

"Certainly, if we see the teacher one, two, or three sessions in person and the classes are held in person, many ambiguities will be removed. Certainly, with in-person classes, we can ask our questions much better and learn the material more deeply and better." (Student No. 1)

2) Student learning support

One of the instructors participating in the interview points out the importance of assisting and virtual networks that can be used to promote students' learning and better understanding.

"I always make a WhatsApp or Telegram group, and most of the learning occurs there when I'm there, and if a student asks a question, I can answer it." (Instructor No. 5)

3) Support by the instructor

One student points out the importance of the teacher's role in the dissertation process from beginning to end.

"Our expectation is that they will show us the way well so that we do not do anything again. Good and acceptable body presentation will help us in the proposal so that we do not suffer too much so that the instructors may correct and return our dissertations and accompany us throughout the dissertations." (Student No. 9).

4) Monitoring the student's educational status

One of the instructors pointed out the importance of student monitoring and not leaving students in e-learning alone. He stated that they should limit education years because this will accelerate the student's graduation."The problem with e-learning is lax students, and humans instinctively relax where they are lax. If they don't have limitations for their education years, we won't know what happens to their education years. They like to finish soon; who doesn't like it?" (Instructor No. 5)

5) Correct and transparent student assessment

One of the interviewed students described her experience of how to evaluate while studying in e-learning in such a way that she believes that evaluation should be comprehensive and complete and should not rely on only one specific aspect."The evaluation was only on the assignments, and the assignments were all copies, and they did not check at all why the type of assignment is just this and there are no other things next to these assignments or online tests. That evaluation should be really a real evaluation of that person. It was not possible." (Student No. 7)

3.2 Main Category/Interactions and Communications

This category refers to the supportive needs that the student feels in communicating between different groups, including three subcategories: "communication with the instructor", "communication with peers", and "communication with graduates."

1) Communication with the instructor

One of the participants pointed out that in e-learning, especially at the postgraduate level, one of the factors that can be supportive for the student is the possibility of quick access to the instructor when necessary."The person should feel that he can send a quick message to the teacher whenever he wants, and he will see and respond; this itself can create a good feeling of support in the student." (Student No. 9)

2) Communication with peers

Regarding the importance of communication with classmates, one of the participants in the interview commented as follows."If an instructor or university does something that students can interact with in groups, it can partially solve this problem (feeling isolated and lonely) and make those connections easier to form" (Student No. 5).

3) Communication with graduates

In an interview, one of the education officials said that the formation of graduation centers after graduation plays a supportive role for the student in various ways and ensures

that the student does not lose contact with the university after graduation."Our students should have graduation centers. The system that gathers students to celebrate graduation. In fact, it provides the support that one is in touch with both the university and his classmates even after graduation, and perhaps if there is support for their profession in those specialized associations, this will happen" (head of education and Instructor No. 2).

3.3 Main Category/Empowerment

Empowerment refers to supportive needs to become more empowered to study in virtual courses and includes two subcategories "instructor empowerment" and "student empowerment."

1) Instructor empowerment

The view of one of the educational deputies participating in the interview was that not every instructor is suitable for teaching in e-learning and instructors who are somewhat capable in working with software and technology, or at least interested in learning and teaching in this field should be selected. "They have a phobia of working with software and technology, you know? Because of this, we should not bring not every instructor; we should employ an instructor who is really interested, knows some technology, or at least not afraid. Some people are actually afraid."

Instructor No. 2 referred to the self-regulatory discussion and the need to teach this to the student and empower the student.

2) Student empowerment for e-learning

"Self-regulatory personality structure discussions should be declared before they enter; they should be highly self-regulated; they should not be very dependent on in-person communications, and that it should not be that someone is looking for them to do something; they should know that this is not possible in virtual education."

3.4 Main Category/Structural Support

It includes structural and organizational support in e-learning and consists of five subcategories: "Appropriate organizational support in education", "material and spiritual support", "appropriate infrastructure for e-learning", and "paying attention to individual affairs of the student", and "the instructor evaluation by the student".

1) Appropriate organizational support of education

Instructor No. 5 said that education experts should be justified that the situation in e-learning is sometimes different from in-person education and the student needs special support. "All of this should be oriented. For example, the expert who is there should not think like an expert in a college. Some education experts still think traditionally. For example, we should ask for something. We should send an official letter. Let's send it and get it signed." (Instructor No. 5)

2) Economical and spiritual support

It is inferred from all the statements of the participants in the interview that material and spiritual support in e-learning is a primary aspect in supporting students. One of the students expressed the need for student support in this regard: "In terms of the psychological realm of motivation to continue education, for example, one is what the benefit of the field is during one's employment and what its application is, which can also be helpful." (Student No. 1)

3) Suitable infrastructure for e-learning

According to one of the instructors teaching e-learning courses, the need for changes in the e- learning curriculum is felt, and changing the course curricula based on the conditions and characteristics of e-learning can play a supportive role for students.

"In virtual space, I think something has to change in the curriculum itself. Finally, some of the evaluation methods, some of the teaching methods that you wrote in the curriculum are not possible in virtual education; you have to add something else." (Instructor No. 5)

4) Importance of individual affaires of the student

The instructors and students participating in the interview emphasized the importance of paying attention to the individual affaires and problems of the student. A student who was diagnosed with cancer while studying described his experience as follows: "Of course, I was in a state of illness and secluded somehow, because of the side effects of the thoughts that came to me, I might not have had the initial motivation, and continuing my work was questionable. It would have been very helpful if the university or instructor supported me in this field." (Student No. 10)

5) Instructor evaluation by the student

Several students referred to the issue of student evaluation of the instructor. One of the interviewed students complained about the inattention of the education officials and the department to their opinions and evaluations of the instructor. "We evaluated the instructors and said that one of the instructors was scientifically good but did not have the power of communication and his class is boring. We said it, but we did not see any feedback that the instructor wants to change." (Student No. 8).

To design a model of student support in e-learning, the panel of the main categories extracted from content analysis in the expert session was compared in pairs to prioritize the domains through AHP based on [20, 21, 23, 25] (Tab. 4).

Table 4 Results of AHP

Criterion	Weight	Priority	Explanations
Learning – Teaching	0.451	1	coefficient of inconsistency = 0.03
Empowerment	0.119	4	
Structural support	0.261	2	
Interactions and communication	0.169	Learning - Teaching	
		Empowerment	
		Structural support	
		Interactions and communications	

The following model was designed according to the results of prioritization of domains and using the opinion of e-learning experts.

Finally, the following model was designed by forming an expert panel and using the opinion of e-learning experts (Fig. 1).

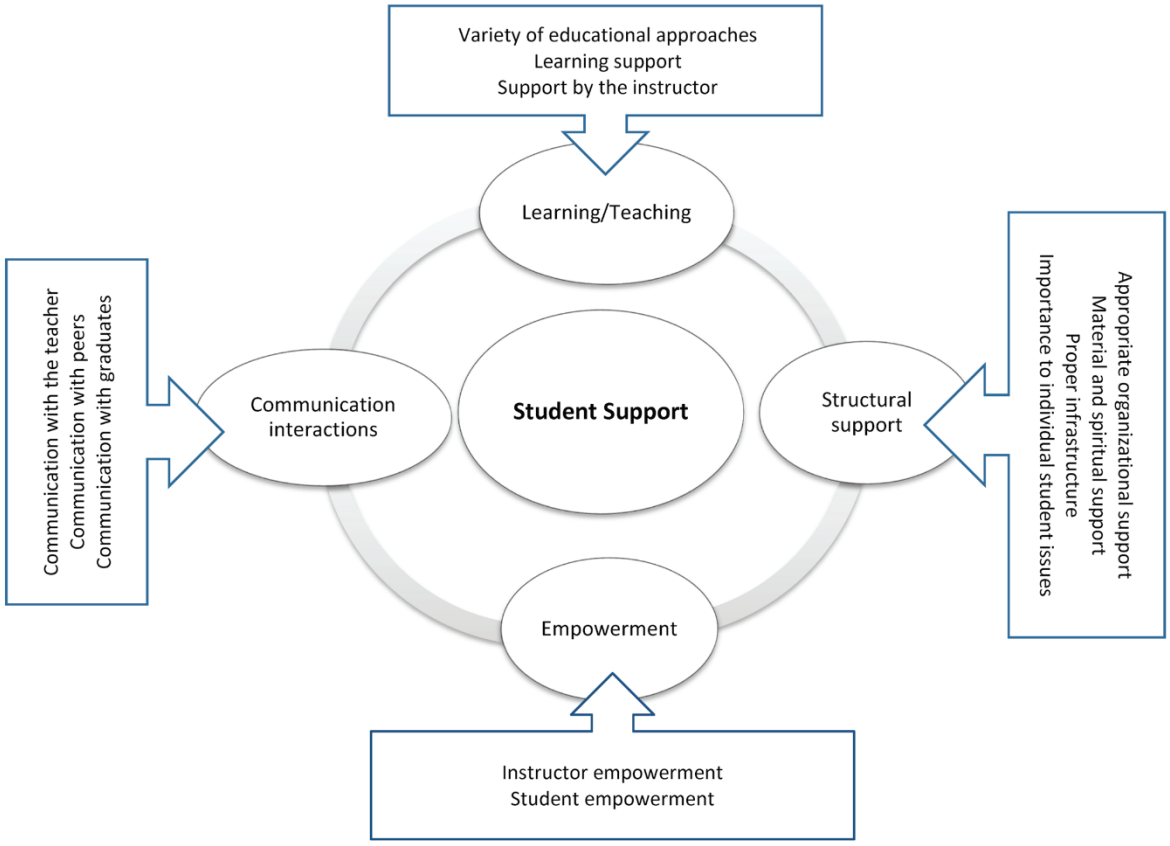

Figure 1 Conceptual model of Student Support in Distance Learning

4 DISCUSSION

The present study was conducted to design a student support model for post-graduate students of medical universities who study virtually and obtain a virtual degree.

According to the participants' items, diversity of approaches and educational contexts, support for student learning, support by the instructor, monitoring the student's educational status, and correct and transparent assessment of students are the examples of student support; it is called teaching-learning category in this model. Simpson presented a three-dimensional model of student support; one of the main categories was dedicated to the cognitive domain, in which student support is taken into account in the field of better learning of courses, proper assessment and correct feedback, and improving learning skills to learn courses better [2]. Also in the Jung model, one of the main classes of the model is dedicated to the cognitive domain, which includes supporting the student in order to evaluate correctly, giving feedback, and other activities in order to better learn and prepare for the exam [16].

The interviewees emphasized the importance of receiving the necessary support to improve the learning of the courses and pointed to the need for support from instructors and the university to learn as many courses as possible.

Many of the interviewees mentioned support in communication with the instructor, peers, and the graduates. However, the majority of interviewees emphasized the need for supporting interactions and communications. The interviewees stated that communication with the teacher is weak in e-learning systems, and in most cases, communication is not performed properly. Also, communication with peers and graduates of the field of study leads to better and deeper learning. However, existing student support models pay less attention to this issue, perhaps due to the difference in the formation of online classes and the possibility of making video calls in the e-learning systems of developed countries due to the availability of high-speed Internet platform [26].

Dalbani [17] wrote that the distance between teacher and student in e-learning has a negative effect on student learning, so proper interaction and communication between teacher and student in e-learning seems necessary so that students do not feel alone.

Interviewees in this model pointed to the importance of teacher and student empowerment as an example of student support in e-learning. Existing student support models do not explicitly address the issue of empowering faculty and students for e-learning, perhaps because e-learning courses are older in the countries that host these models.

Chatpaka Ratana [5] pointed out that the lack of self-management skills in e-learning students causes them to drop out. Adelman [18] also stated that some students drop out of e-learning courses because of poor self-management skills and motivation.

One of the main classes of most of the existing models of student support is structural and systematic support. For example, Jung [16] in his model asked whether the system

and structure of e-learning support the student in the student support system. This area includes support such as assessing student progress during the course, evaluating and validating the university education system, technical support, etc. Adelman [18] stated that all those involved in education and structural resources in the e-learning system should be considered an integral part to support services.

In the five-dimensional model of Jung, presented for East Asian countries, a separate category called gender is addressed, which in the view of recipients of e-learning services, it is necessary to pay attention to this area in supporting students in East Asian countries. In the present study, none of the participants specifically mentioned gender instances in relation to student support. It seems that this issue is related to cultural differences and the conditions of education and work in the e-learningin the country, which is almost equal in both genders. Also, in the Lap model, student support services are divided according to the course and time stages of study [19]. Also, Mohammadi Mehr [8] emphasized different support needs in time stages. Most of the interviewees pointed out that they need different support to continue their education in different stages of their education.

In general, the model presented in this article, which refers to the importance of four areas of teaching-learning, structural support, interactions and communication, and empowerment, is the result of the opinions of the interviewees who mentioned the need to support students in these areas in the interviews.

5 LIMITATIONS

Due to the corona epidemic and travelling problems [27], some of the interviews had to be conducted by telephone, and expert panel meetings were also held virtually. In the systematic search, only English articles were included in the study. Another limitation was the problems that occurred after the coronavirus outbreak, and some of the interviews had to be conducted in distance, and the interviews were limited to people from selected universities in the country.

6 CONCLUSION

Although the present extracted model is in many ways consistent with existing models of student support in the field of e-learning, there is a need to use a student support model consistent with the views of e-learning stakeholders and compatible with the cultural, economic, social, and educational conditions of the country due to cultural, social, and economic differences between countries. Therefore, to establish student support systems, education officials and decision makers are suggested to use the current model, which is in line with the needs of e-learning students and the opinions of instructors and educational officials in the country.

Conflict of Interest

I hereby declare that the authors did not express any conflict of interest.

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Authors' contacts:

Ahmad Parizad
Department of Medical Education,
Faculty of Medicine, Tehran University of Medical Sciences,
Tehran, Iran

Aeen Mohammadi
(Corresponding Author)
Department of E-learning in Medical Education,
Center of Excellence for E-learning in Medical Education,
School of Medicine, Tehran University of Medical Sciences,
Tehran, Iran
aeen_mohammadi@tums.ac.ir
aeen@yahoo.com

Rita Mojtahedzadeh
Department of E-learning in Medical Education,
Center of Excellence for E-learning in Medical Education,
School of Medicine, Tehran University of Medical Sciences,
Tehran, Iran

Mandana Shirazi
Department of Medical Education,
Faculty of Medicine, Tehran University of Medical Sciences,
Tehran, Iran

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The Role of Information and Communication Technology in Improving the Financial Performance of Hospitals

Biljana Markovic*, Ante Roncevic, Marina Gregoric

Summary: We are witnessing that the healthcare system of the Republic of Croatia is faced with numerous challenges, especially financial ones. Many activities are needed to improve the condition. In this paper, the emphasis is on the application of information and communication technology (ICT) as a tool for reducing costs and increasing income. The hypothesis of the work is that with the help of ICT we can directly, but also indirectly, by applying ICT through the so-called Dynamic Balanced Scorecard (DBSC) to influence business improvement. The DBSC method enables the evaluation of financial operations indirectly through employee education, optimization of business processes and increased patient satisfaction. In addition to the DBSC method, analysis of the collected literature, cost-benefit method and case studies are used to test the hypothesis. Regarding structure of the work, the introduction explains the context of the hospital's operations, defines the goals, hypothesis and research methods. This is followed by a description of the conducted research. The conclusion contains final considerations as well as suggestions for future research.

Keywords: Balanced Scorecard; business; costs; hospital income; information and communication technology

1 INTRODUCTION

The application of information and communication technology (ICT) in all areas of human activity is indispensable if we want to be efficient and effective. It is the same with healthcare. The subject of the research is the impact of ICT on hospital operations. The research aims to determine whether ICT helps reduce/rationalize costs and increase hospital revenue. The hypothesis is as follows: by applying ICT in the hospital, it is possible to reduce/rationalize costs and increase revenues, i.e., increase business performance. The work uses scientific methods, namely: literature study, observation, measurement, analysis and case study (specifically, the work focuses on the in-depth investigation of the phenomenon - the application of ICT to improve the financial result in the hospital, directly and indirectly, through the dynamic Balanced Scorecard (BSC) method; only the correlation coefficient is used from statistics).

The paper presents in detail the so-called Dynamic Balanced Scorecard (DBSC) method, which is a modification of the classical method. It is explained in detail and it is shown how it can be carried out using ICT. It is important to emphasize that the described research "can be repeated with the same effects". Dynamic BSC represents a scientific contribution because it represents an original way of implementing the BSC method. Dynamic BSC method is used for indirectly confirmation the hypothesis by determining the level of education of employees and their lifelong learning, optimizing internal processes, and increasing patient satisfaction. All of the above brings a better business result. The research will show precisely the parts of the business process in which ICT causes resource savings on the one hand and revenue growth on the other. Through the presentation of results and discussion, we will try to show how it is possible to make savings and increase revenue on a monthly basis. In the end, the conclusions summarize all collected data and give recommendations how to maximize savings. The following is a description of the research.

2 RESEARCH

The survey was conducted in May 2022. Research methods are observation and measurement, and analysis of the obtained results. The research subject is the integrated hospital information system, which consists of several components: hospital, laboratory, radiological, pharmacy, and business information system, nutrition system, and reporting system. All components are integrated at the level of data exchanged between components in the form of XML messages respecting the HL7 protocol. During the research, treating patients "from admission to the institution to discharge" was observed. Furthermore, ICT support in certain parts of the business process was observed, and the cost/benefit method showed savings or revenues caused by ICT. In addition to a direct cost reduction and an increase in revenue, there was also an indirect increase in business performance with the help of Balanced Scorecard method [1, 2].

2.1 Description of the Process "from Admission to Discharge"

There are two essential admissions to the hospital: admission to the outpatient department and admission to hospital treatment. Admission to hospital treatment can be planned or urgent (through a unified emergency hospital ward). In the polyclinic, the course of treatment is short: the first control examinations and contracted specialist examinations are performed there. The duration of hospital treatment is two or more days. Both in the polyclinic and in-hospital treatment, diagnostic tests are an indispensable part. The two primary groups of diagnostic tests are radiological and medical-biochemical tests. During hospital treatment, patients were provided with medical materials, medicines,

and meals. Upon admission, referrals are automatically withdrawn from the Central Health Information System of the Republic of Croatia (CEZIH), and upon discharge, there is, i.e., a discharge letter sent to CEZIH. All treatment costs are transferred to the invoice and sent to the Croatian Health Insurance Institute or are invoiced to the patient if there is no health insurance.

Through observation and measurement, elements of the described business process have been identified in which ICT helps reduce/rationalize costs and increase revenues. More details are below.

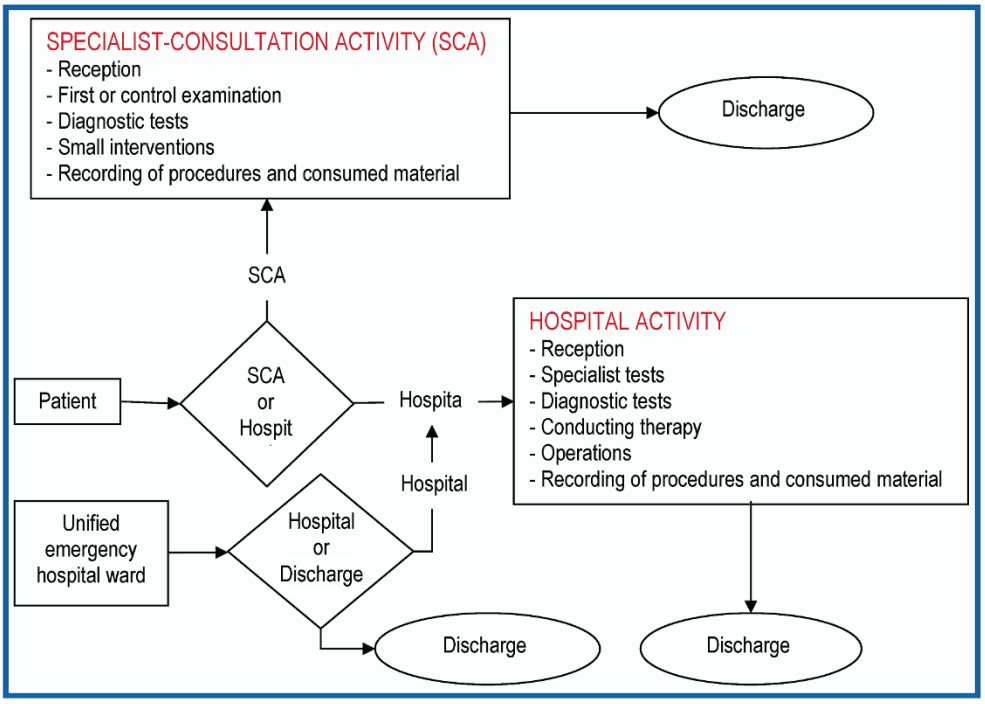

Figure 1 Process "from admission to the institution to discharge patient"; Source author's research

2.2 The Role of ICT in the Process "from Patient Admission to Discharge"

All parts of the business process "from admission to discharge of the patient" are computerized, i.e., supported by an integrated hospital information system. The following elements of the business process in which ICT enables savings and increased revenues will be emphasized in the following subchapters.

2.2.1 Direct Savings

A) SPECIALIST-CONSULTATION ACTIVITY

In inpatient admission activities, the use of ICT, speeds up the process. The administration process is shortened, and nurses have more time for health care. In a unit of time, it is possible to receive a more significant number of patients thanks to the so-called—eOrdering system. There is no need to re-enter general patient data and data from the referral because they are directly transferred from the Croatian Health Insurance Institute (HZZO) information system. Everything is done paperless. The computer equipment and the applications used to receive patients needed to receive patients are a one-time expense. As an example, the paper referral form costs 0,96 €. The hospital has 48 admission sites and an average of 50 patients per site during the working day. In the analysis, we took 20 working days per month. The cost of paper that disappears with the use of ICT only at admission is: 48 (work sites) × 0,96 (price of one referral form) × 50 (patients) × 20 (working days per month) × 12 (months) = 554.250,45 € per year, provided that each patient has only one referral (namely, one patient may have more than one referral during one visit). That is minimal savings. In inpatient examination activities, the physician does not have to print referrals and does not have to print the results of radiological or medical-biochemical tests already see it all on the screen. The price of one A4 paper is 3.32 € / 500 pcs = 0.01 €. The savings on printing paper when examining a patient are minimal: 48 (work sites) × 0.01 (unit price of A4 paper) × 50 (number of patients during the day) × 20 (twenty working days) × 12 (months) = 3.187,25 €, assuming that only one sheet of paper is printed out per patient. In the case of discharge activities, the finding is not printed but is sent as a message to the smartphone and to the CEZIH, from which the patient's qualified general practitioner can retrieve the finding. The savings here are also 3.187,25 € (48 (work sites) × 0.01 (unit price of A4 paper) × 50 (number of patients during the day) × 20 (twenty working days) × 12 (months).

Revenue can be estimated indirectly by applying Balanced Scorecard methods. Because more patients are received and treated in a unit of time, more services and procedures could be invoiced, and consequently, the revenues from HZZO will be increased. So, the total revenue of the hospital will be increased. The most significant savings

are with radiological diagnostics. Only thanks to films, fixers, and developers are not used; the average monthly savings is 66.361,40 €. This means that the average annual savings are 796.336,85 €. This number alone covers the annual cost of the hospital, radiological, laboratory, business, pharmacy information system, and nutrition information system. In addition, these savings cover the annual gross salaries of IT staff. Furthermore, thanks to the prescribed guidelines built into the laboratory system (e.g. that CRP - C reactive protein (type of test) does not need to be done more than 24 hours), it is possible to rationalize the prescribing of medical laboratory tests in hospital treatment and consequently achieve savings on reagents used in the search process. The report obtained from the reporting information system shows that in 2021 the savings on medical materials used in tests within the medical-biochemical laboratory amounted to 27.871,79 €.

B) HOSPITAL ACTIVITY

When hospital activity is observed, the most significant savings are realized through *targeted therapy.* Namely, the pharmacy and hospital information systems are interconnected, and thanks to that, it is possible to carry out targeted therapy that doctors and nurses prescribe. Thanks to targeted therapy, departmental stocks are reduced by 40%, which amounts to an average of 46.452,98 € per month, i.e., 557.435,80 € average annual savings. In addition to targeted therapy, the hospital information system allows accurate recording of the so-called. "stac" (procedures performed on the patient, medicine and medical supplies used). They also enable accurate recording of diagnostic and therapeutic groups based on which the HZZO pays funds to the hospital. An important item contributing to the hospital's savings is the use of *reserve antibiotics (alternative so-called generic drugs that contain the same active substance as the originals but can be purchased on the market at a lower price).* The application of ICT enables their precise administration. Annually, savings in the use of antibiotics equal 278.757,90 €. Therefore, thanks to the application of ICT, if used only in the examples listed above, further savings of 2.220.346,41 € is possible**.** It is important to emphasize that the prerequisite for achieving these savings is for health employees to have appropriate competencies that enable them to use ICT effectively. In addition to the listed direct savings calculated as described above, it is possible to monitor the increase in income with the help of Balanced Scorecard [1, 2] method in the manner explained below.

2.2.2 Indirect Savings and Income

Indirect savings and income can be estimated using the Balanced Scorecard (BSC) methods (ibid). The essence of this method is to observe the financial result[1] indirectly through the improvement of internal processes in the hospital, employee competence and patient satisfaction. ICT plays a vital role in all three elements. It enables faster, efficient, and efficient business processes by optimizing them and reducing redundancy to a minimum. By working with an integrated hospital information system [3-5], employees improve their competencies, become computer and information literate, and have more time to provide medical care. Patients are more satisfied because the whole process is faster, waiting time is reduced, nurses and doctors have more time to dedicate to the patient, and they do not waste time on administration. In addition, patients do not have to come to the hospital just to order or pick up results, which contributes to their satisfaction. All of the above leads to better hospital operations. In order to achieve all of the above, the internal processes and activities must be continuously supervised, the training of human resources must be taken into account, and the quality of health care providers must be monitored.

2.2 3 Balanced Scorecard – Conceptually

Since we want to continue showing the innovative application of the BSC method (Dynamic BSC), the intention here is to recall the basic concepts of the method. The Balanced Scorecard (BSC) method was developed by Kaplan and Norton [1], [2]. They recognized that the success of a modern organization cannot be measured only through the observation of financial results. Much more attention should be paid to improving processes, training employees and creating new ways of connecting with customers. The BSC method enables the implementation of the strategy and a balanced view of the organizational goals defined in the strategy. Kaplan and Norton talk about four basic perspectives on the organization: finance, customers, internal business processes and learning [6-9]. Variations of the BSC method add a fifth area (e.g. the environmental dimension) or replace all perspectives with one that is a uniform reflection of their mission and strategy. Nevertheless, the four perspectives described by Kaplan and Norton are generally applicable in different organizations. Thus, BSC can be applied in a general hospital, with the perspective of "Customers" being replaced by "Patients."

Why use other measures in addition to financial ones, such as benchmarks for growth and development, benchmarks for improving customer relations, and internal processes? In today's business environment, the most important resource is information. Only financial measures that measure "tangible" assets do not allow an organization to face market competition in the information age. Namely, managers must have as much information as possible about "untouchable" assets, such as various connections, alliances, and abilities that are becoming an essential factor. Today, in over 75% of successful organizations worldwide, an important factor is the so-called intellectual property, i.e., educated employees [10]. Today, machines do routine work, and labour is not needed for such work, but employees are increasingly engaged in creative work, innovation, analysis, and similar work. The BSC method helps management take into account the above facts and manage critical business processes and intellectual capital.

[1] Perform Magazine, Volume 1.2. (2003), Panorama Business View Inc., London

2.2.4 BSC in a General Hospital

In the general hospital, the achievement of strategic goals is monitored with the help of BSC in a specific way [11-13] with the application of the correlation coefficient. For each strategic goal, there is a table in Excel that changes continuously, dynamically (every three months) depending on the observed changes. The dynamic character of BSC management and the use of the correlation coefficient specific to the hospital represents a modification concerning the "classic" BSC. The following will briefly describe the model of BSC in a general hospital. The idea was to create a simple and functional tool for managers in health care institutions, which would effectively and efficiently define and monitor the implementation of the strategy. The basic assumptions for this are:

- Use a simple, accessible, and understandable tool (Excel)
- Possibility of seeing all critical information on one worksheet
- Ability to run simulations (by changing data to change performance); that is why it is a dynamic BSC.

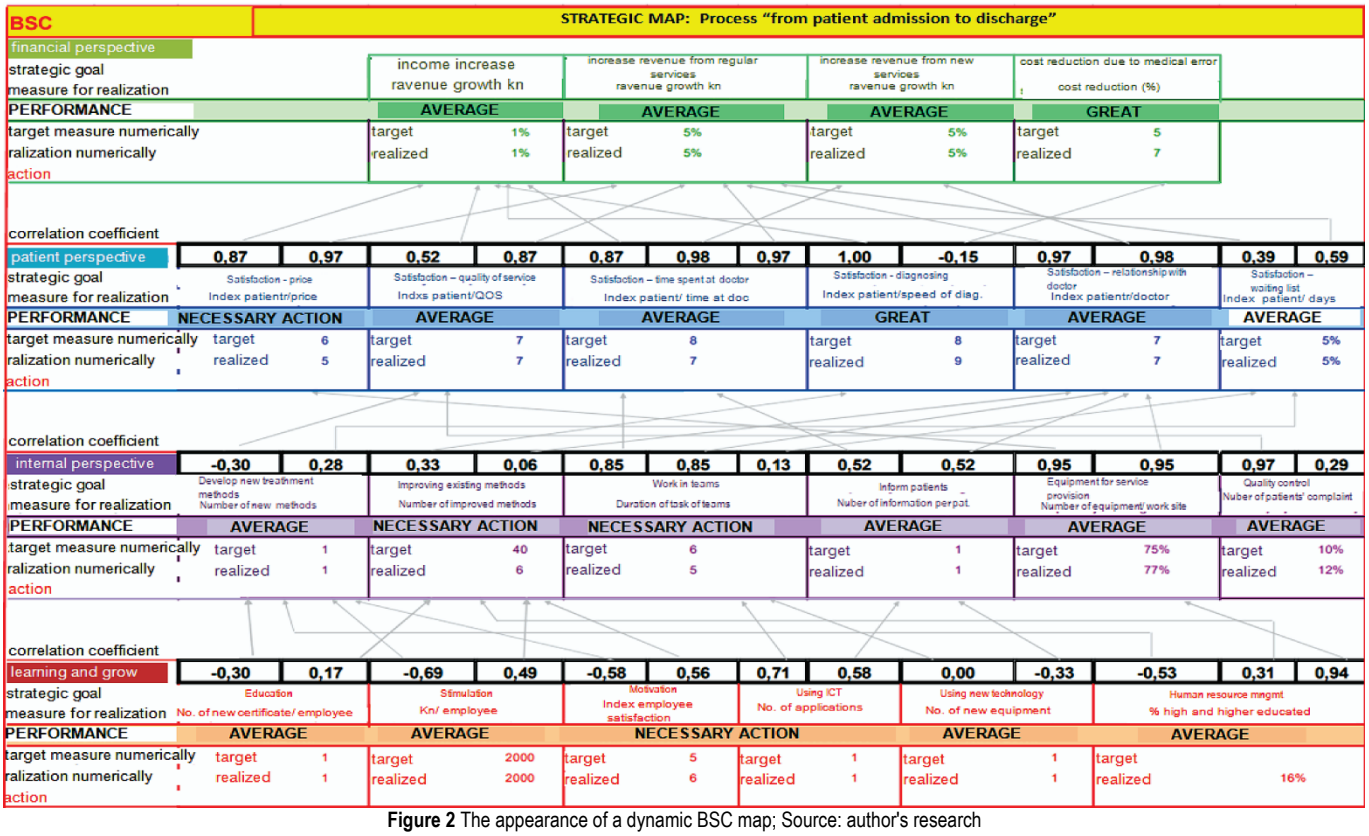

Figure 2 The appearance of a dynamic BSC map; Source: author's research

Background table is defined for every strategic goal

number of new certificate/employee

	evaluation	target	realized	index
2006	7	2007		
I	7	1	1	100,00%
II	5	2	1	50,00%
III	6	3	2	66,67%
IV	8	2	3	150,00%

Figure 3 Background table; Source: author's research

The display elements of the BSC map, in this approach, are:

- Background tables (for each strategic goal)
- Defined for each perspective (internal processes, employee education, patients, and finances): strategic goal(s), achievement measure, numerical measure set, numerical achievement, action, correlation coefficient, and performance.
- Relationships between strategic goals (their importance depends on the correlation coefficient).

For each perspective within the BSC, the following is monitored:

- Correlation coefficient
- Strategic goal
- A measure to achieve a strategic goal
- Performance (i.e., performance evaluation).
- The planned measure, i.e., the goal expressed numerically (must be measurable)
- Realization expressed numerically
- Action (which must be taken if the correlation coefficient is extremely poor).

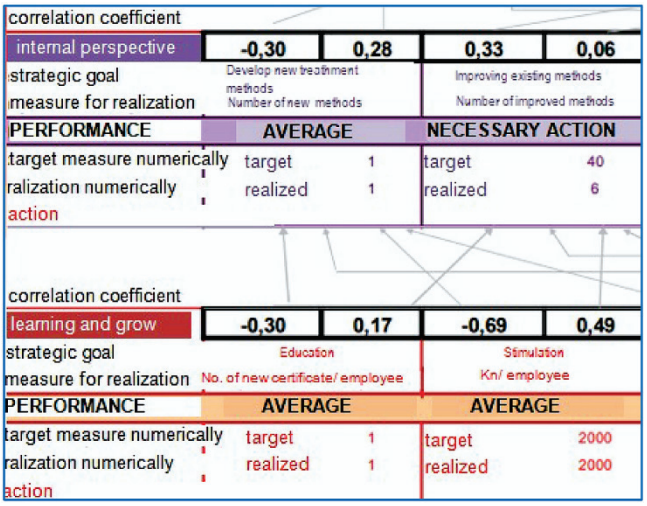

Figure 4 What is monitored for each perspective; Source: author's research

The procedure of dynamic maintenance of the BSC map (specificity of the hospital - it is not in the classic BSC):

- Four perspectives are observed: financial, patient, internal processes, learning and growth.
- Each perspective is divided into critical processes and indicators relevant to the business.
- For each process or indicator within each of the perspectives, strategic goals and measures have been set through which the achievement of these goals will be monitored (quarterly).
- Monitoring of the achievement of goals is also done quarterly, through actual physical achievements and by using the evaluation system (surveys of patients and employees - the work of all doctors at the workplaces and the satisfaction of all patients who came to the doctor in the same quarter are observed
- For each quantitative level of achievement, an evaluation is given in the form of a grade, and these grades are updated on a quarterly basis (there are updated formulas in the tables).

Goal setting and performance monitoring are conducted at the level of services and departments responsible for individual indicators, while universal indicators (most from a learning and growth perspective) are monitored by all relevant services and departments. At the end of each month, department managers enter the values achieved, and the goal execution and the grade are calculated automatically. The scale of evaluation ranges mainly from 1-10, but lower and higher values can be obtained, depending on the size of the deviation from the set goal. For example, a score of 1-4 can be interpreted as poor performance indicators, 4-7 as average, and 7-10 as excellent performance.

For the first year of the BSC introduction, the indicators' assessments are based on the assessments from last year.

Expert assessments make them, and each subsequent year is tied to the previous year's grade. When setting a quarterly target for each indicator, one should strive for actual values, which are not too high or difficult to achieve. If the goal's achievement deviates very negatively from the set values, it is necessary to take action, which is written on the main strategic map. Correlation *coefficients* help diagnose the problem of not achieving goals and taking the right action, i.e., indicators of the strength of the relationship between the interactions of different variables (indicators), primarily strategic goals. The arrows in the BSC map (Fig. 2, Fig. 4) show a cause-and-effect relationship between strategic objectives. Correlation[2] [14, 15] is a function of quarterly achievement between two strategic goals that are causally related. The correlation (trend) of two variables (correlation) can be positive or negative, and the correlation ranges is from –1 to 1. If the coefficient is closer to these values, there is a strong negative or positive correlation. If it is equal to 0, the correlation between the two variables does not exist, and that action needs to be taken. Every action in this model is recorded in an Excel spreadsheet. For each strategic goal, the action to achieve the goal is defined. An example of positive and negative correlation is: greater staff flexibility is likely to result in more patients examined - a positive correlation, and at the same time less expected average waiting time for a consultation or specific patient service - a negative correlation.

Advantages of using the correlation coefficient:

- They give a dynamic picture of the business - business indicators are constantly changing - assuming for the better if a decision is made to accept the goals and measures according to the BSC methodology, their monitoring, and evaluation. In this way, it is possible to get the up-to-date parallelism of changes in the variables, and the strength of their possible correlation (this reflects the dynamism of this BSC map)
- When the correlation coefficient is more significant than, for example, 0.8 (a series of measured data greater than, say, ten quarters for reliability). It could be concluded that the two variables correlate significantly and that changing the causal variable can positively affect the target variable. This could be tested, for example, by keeping all other causal variables believed to affect the target variable constant, increasing or decreasing the selected variable, and measuring its impact on the target variable in the future. For example, if it is assumed that productivity is affected by all variables from the lowest perspective (learning and growth) and certain variables from the second (upper) perspective, such as investment, service structure, diagnostic errors, etc. Accordingly, it is possible to change only the age or educational structure in a given period (while keeping other variables that can be influenced as constant) and measure the impact of their changes on the change in productivity. Thus, this approach allows for a good and reasonably precise management tool which can influence key objectives at a minimal cost.

[2] Connectivity Analysis. Retrieved May 20, 2022, from http://statinfo.mefos.hr/1920/pdbstat/PDBS-V4.pdf

Advantages of the displayed BSC map:

- Since the correlations of variables are entirely intertwined, and there are many variables and different data sources (actual data, surveys, etc.), it is almost impossible to manipulate the data, and even if such a possibility occurs, it is detected very quickly
- Easy and fast access to all important data for the user manager, practical (only one page), all data is automatically updated when department managers enter achievements for each quarter - no man needed to control and change it all (avoiding human factor errors)
- Easy to enter execution data; each responsible person will have approx. 5 - 10 tables, i.e., 5 - 10 data sets that will need to be entered quarterly, which does not require much time, and the tables are made in the well-known MS Excel program.

Disadvantages of the displayed BSC map:

- In order to obtain some correlation coefficients between pairs of variables, it is necessary to have a fairly long series of data (it is recommended to have data from at least ten periods, i.e., quarters, in other words, 2.5 years) to be able to draw a correlation conclusion with a certain degree of confidence. This represents a relatively long period of the entire operation of such a BSC.
- It will never be possible to completely isolate the influence of all other variables on the target variable, so it will never be possible to say with 100% certainty that the correlation coefficient between two variables involves the interaction those two variables only.
- This model of BSC assumes a cause-and-effect relationship in only one direction, which is often not the case in practice.

The general hospital-adapted BSC model is used because:

- The presented method of monitoring the implementation of the strategy is defined quarterly but can also be on a monthly, weekly, or even daily basis.
- It is convenient because it is easy to use and intuitively clear
- It is suitable for simulations because by changing the input parameters in the background tables, the map also changes
- "Bottlenecks," i.e., critical performance, can be seen very clearly, so it is possible to react quickly.

3 CONCLUSION

This paper pointed out the possibility of using ICT to influence the financial result of the hospitals. Research of parts of the business process "from the admission of the patient to the hospital to discharge" shows exactly how much savings can be achieved. In addition, a modified BSC model is presented, which is applied in the hospital to better manage the achievement of strategic goals through monitoring the implementation of specific activities and thus affecting the improvement of financial results. Finally, the aim of the research was achieved, i.e., it was determined that ICT implementation helps to reduce costs and increase hospital revenues.

It is important to emphasize that in order to exploit the full potential of ICT, hospital staff must have specific digital competencies. This means knowing ICT (in this case, Excel) is necessary, but this is not enough. Namely, a digitally competent person should know how to place the collected information in a mutual relationship and create new knowledge. Digitally competent employees are able to make optimal use of the ICT at their disposal and thus better implement the dynamic BSC method, which indirectly enables the improvement of the hospital's financial results. Further research should be directed on the new application of the dynamic BSC method throughout the health system. The presented method should be standardized in terms of the strategic goals that will be followed, the fulfilment of the key performance factors of health institutions. Standardization would enable the application of the method in other health institutions that have certain specificities in relation to hospitals.

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Authors' contacts:

Biljana Markovic, PhD
University North,
Jurja Krizanica 31b,
42000 Varazdin, Croatia
E-mail: bimarkovic@unin.hr

Ante Roncevic, PhD, Full Prof.
University North,
Jurja Krizanica 31b,
42000 Varazdin, Croatia
E-mail: anroncevic@unin.hr

Marina Gregoric, PhD, Assist. Prof.
University North,
Jurja Krizanica 31b,
42000 Varazdin, Croatia
E-mail: magregoric@unin.hr

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Towards the Analysis of Reliability Index of Steel Frame Equipped with TADAS Yield Damper

Parviz Hosseini Sarjou

Abstract: During an earthquake, a considerable amount of kinetic energy from the ground acts as a lateral force on the structure, and this energy causes damage to the main components of the structure, including beams, columns and joints. To reduce the effects of earthquakes on the structure, one of the best methods is dissipation of the energy applied. For this purpose, there are various methods, one of the most practical of which is dampers. Dampers are attachments to a structure that dissipate energy and reduce damage to structural components. The present study examined the TADAS yield damper (Triangular Added Damping and Stiffness) and reliability of the structure equipped with this type of damper (particularly the reliability index) considering the uncertainty in ground motion (ground acceleration) and duration of earthquake. To achieve the objectives of the study, reliability index of the structure was calculated and compared in two modes, steel frame with damper and steel frame without damper, based on criterion of failure and drift and base shear. The results show that dampers dissipate energy from the earthquake and improve reliability and, consequently, reduce failure risk.

Keywords: energy dissipation; failure criterion; reliability; TADAS damper

1 INTRODUCTION

One of the most effective methods in analysis, decision making for component selection and structural design is application of probabilistic methods. Reliability of structures is a special method of applying probabilistic methods in structures [1]. There are two main methods for analyzing the reliability of structures, which include: 1) theoretical analysis of structural reliability, including first-order reliability method (FORM) and second-order reliability method (SORM); 2) simulation-based methods, the well-known method being the Monte Carlo simulation, which is more used in complex problems with many random variables [2]. The present study used FORM to obtain the reliability index (β).

The present study first introduced types of yield dampers and characteristics of each and how to model them, and then the FORM method was explained. Finally, three-span and five-story frames with chevron braces were modeled in two modes, with dampers and without dampers, as well as bending frames by software Sap2000. The structure response (roof displacement and base shear) were extracted and discussed by time history analysis in two types of structures subjected to different earthquake accelerations. Using the results obtained from Sap, risk analysis was performed and compared in terms of reliability index.

2 ADAS (ADDED DAMPING AND STIFFNESS) YIELD DAMPERS

Yield dampers are metal devices that can dissipate energy in an earthquake by inelastic changes in metals. These dampers actually yield in flexural, torsional, axial, or shear modes. The first idea of using yield dampers for strength of structures during earthquakes was started by theoretical work of Kelly et al. [3]. ADAS yield dampers are a special type of yield dampers that are described below.

ADAS yield dampers are inactive deformation-dependent energy dissipation systems. These types of dampers consist of X-shaped or triangular iron plates that are placed parallel to each other in the required amount. The damper made of parallel X-shaped plates is usually called XADAS and the triangular type is called TADAS. These dampers are placed in the frame at the end of the chevron braces, so that story drift causes downward movement of the upper part of the device [4]. Usually during an earthquake, when horizontal story drift occurs, a large amount of seismic energy is dissipated due to hysteresis behavior of these dampers. Figs. 1 ÷ 4 show the images of this damper [5].

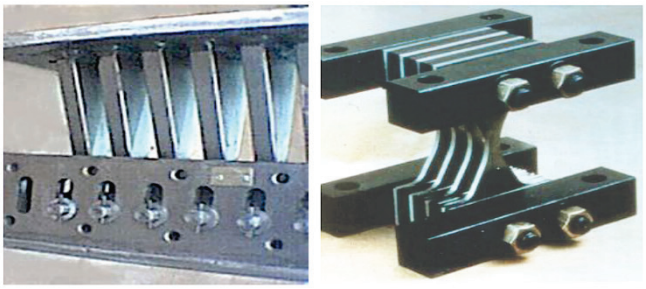

Figure 1 TADAS and XADAS dampers

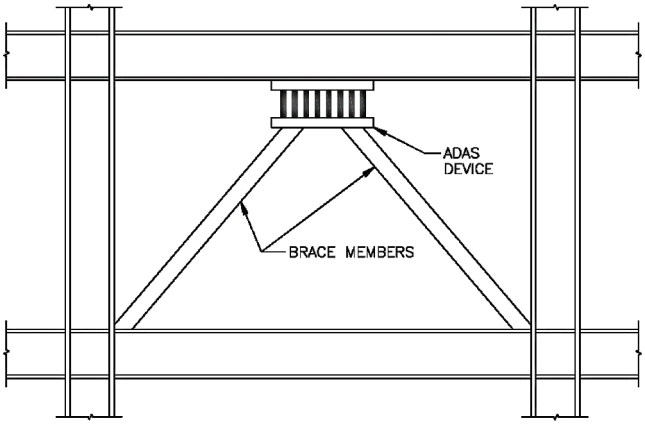

Figure 2 Position of ADAS damper in the frame

These dampers are based on yield of materials and deformation of steel plates, because a large part of input energy is dissipated in the form of thermal energy due to yield of steel plates. In other words, because of the damper shape,

the metal flows when loading, which is done by placing rigid borders in the device so that the damper starts to deform with relative movement in the rigid plates up and down. Seismic experiments on a vibrating table for a 3-story model have shown that attaching the damper to the frame first increases the stiffness and second increases the energy absorption and energy dissipation of the system. For this reason, these dampers are known as added damping and stiffness [6].

Advantages of these components include [6]:

1) Large inelastic deformations are concentrated in ADAS members because these components are designed for this purpose.
2) ADAS dampers can be used in new structures as well as in old and built structures.
3) ADAS dampers explicitly increase viscous damping in structures, thus reducing the structural response to vibration and also reducing the need for dissipation in other structural members.
4) The damper is easily replaced after each severe earthquake.
5) Unlike active control dissipating systems, ADAS energy dissipation system does not require maintenance [7].

Xia [6] studied the effect of various parameters such as yield strength of the part, yield drift, as well as distribution of dampers in the building on the damper behavior. In the studies conducted, three 10-story bending frames with different ADAS elements were examined. The following results were obtained by analyzing these frames.

1) The sliding force of the damper must be large enough to dissipate more energy.
2) Yield drift of the damper should be between 0.0014 and 0.002 of the building floor height.
3) The yield strengths of ADAS components can be considered relative to the design shear forces, and stiffness of its elements can be distributed based on stiffness of the stories in frames without dampers.

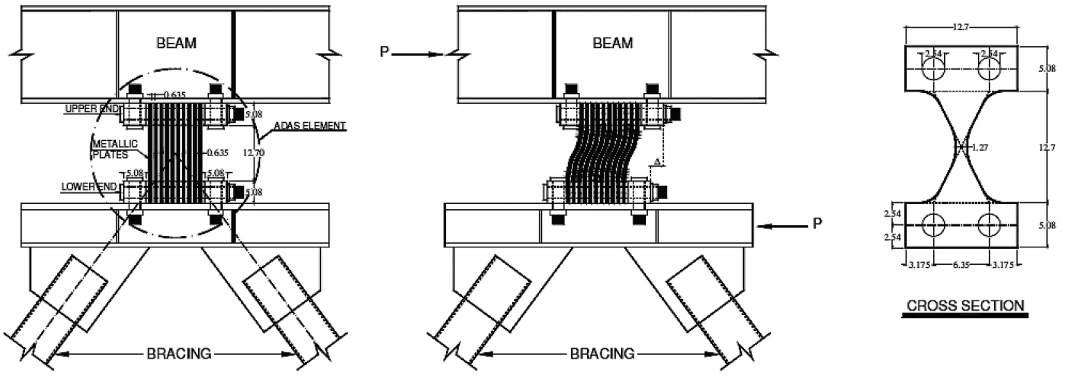

Figure 3 The shape of XADAS damper and its drift by force

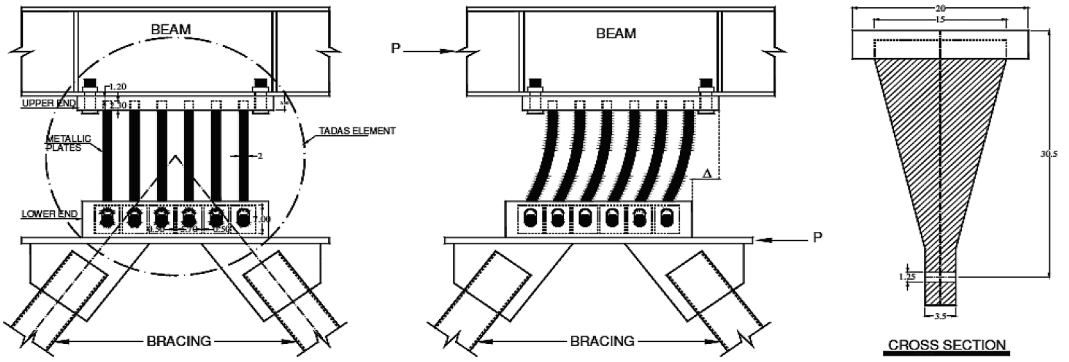

Figure 4 The shape of TADAS damper and its drift by force

Japan and New Zealand pioneered the use of ADAS damping system, but recently this technology has been used in other countries such as the United States, Mexico and India [8].

In 1990, ADAS damper was used in the building of the Heart Clinic in Mexico City. The building has 6 stories and concrete frames. By modeling this structure by Drain and analyzing the frames, it was found that application of ADAS dampers reduces the structural response to earthquakes significantly [6].

Between two types of dampers, present study examines the reliability of TADAS dampers.

3 TRIANGULAR PLATE DAMPERS (TADAS)

Triangular plate dampers are a type of yield dampers, known as TADAS (Fig. 5) [9]. Tsai (1993) studied this type of damper. He first subjected the frames equipped with TADAS dampers to cycle loading; he also considered triangular plates with different dimensions. By obtaining the most suitable dimensions for TADAS component, he dynamically analyzed a two-story steel frame using Electro earthquake accelerograms. The results of these studies showed that a significant reduction in roof displacement occurs with these dampers [6].

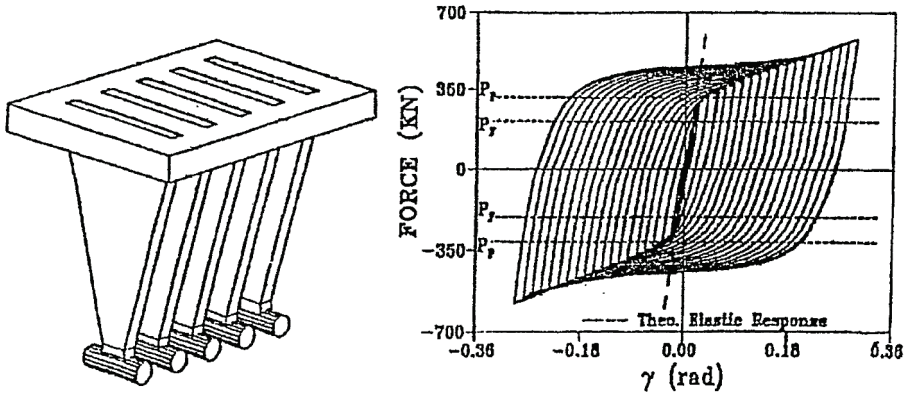

Figure 5 TADAS damper and its hysterical behavior

4 TADAS DAMPER MODELLING

Plastic Wen NLlink is used to model the metal damper by Sap software, since the damper behaves similarly to a full elastoplastic element. In order to introduce parameters of the considered element, the damper specifications introduced by Tsi et al. (1993) were used [10], as shown in Tab. 1.

Table 1 Specifications of TADAS damper in cm and kg

K_{damper}	P_y	Δ_y	*Gap* (Distance from hole to vertex)	*t* (Plate thickness)	*b* (Plate base width)	*h* (Plate height)
1802	988	0.548	1.3	2	15	30.5

For other parameters, the specification presented by Xia et al. (1992) was used [11]. For this purpose, $B/D = 3$, $SR = 3$ were used; thus [12]:

$$\frac{B}{D} = \frac{K_b}{K_d} \tag{1}$$

Where, K_b is relative stiffness of braces, K_d is elastic stiffness of TADAS damper. K_d value is calculated by:

$$K_d = \frac{P_y}{\Delta_y} \tag{2}$$

Where, P_y is yield force and Δ_y is damper yield limit drift.

Value of lateral stiffness of the damping system (damping and bracing) is obtained from the following equation.

$$K_a = \frac{K_b \cdot K_d}{K_b + K_d} = \frac{K_d}{1 + \frac{1}{\frac{B}{D}}} \tag{3}$$

Where, *SR* coefficient is the ratio of lateral stiffness of ADAS system to building story stiffness without damping element (K_f).

$$SR = \frac{K_a}{K_f} \tag{4}$$

5 MATHEMATICAL DEFINITION OF RELIABILITY

Reliability of a system is calculated by calculating the probability of its failure according to the performance function defined by the following integral.

$$P(f) = \int_{g(x)\le 0} f(x)\mathrm{d}x \tag{5}$$

Where, $P(f)$ is probability of failure, x is the vector containing the problem variables, $f(x)$ is probability density function with problem probability variables, and $g(x)$ is system performance function. The above integrals can only be calculated by analytical methods for simple systems with low probability variables [13]. There are many methods for calculating reliability other than direct integral solution; the first-order reliability method (FORM) is one of these methods, which is known as classical first-order method. Fig. 6 shows the concept of failure schematically [13].

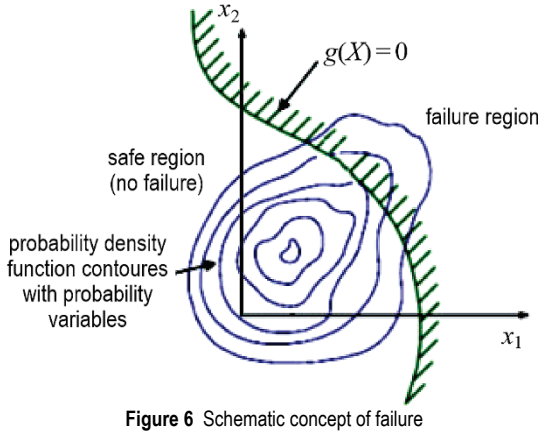

Figure 6 Schematic concept of failure

6 FIRST-ORDER RELIABILITY METHOD (FORM)

First-order reliability methods are the most common methods of estimating the level of system safety. This method is based on linear approximation of limit state function, $g(x)$, with the line tangent to the closest point of this function to origin of coordinates in the standard normal space. Determining this point requires solving an optimization problem that is done in a normal standard space.

This method involves several important steps, which are briefly described below:

Step 1: Converting the space of random variables, X, to the space of standard normal independent random variables, Z. In normal standard space, all random variables are independent of each other and the design point is much easier to calculate due to the independence of variables from each other. In other words, the shape of density with random variables around the origin is symmetric in the standard normal space, and as it moves away from the origin, its value decreases exponentially [14]. This step of the analysis is shown schematically in Fig. 7.

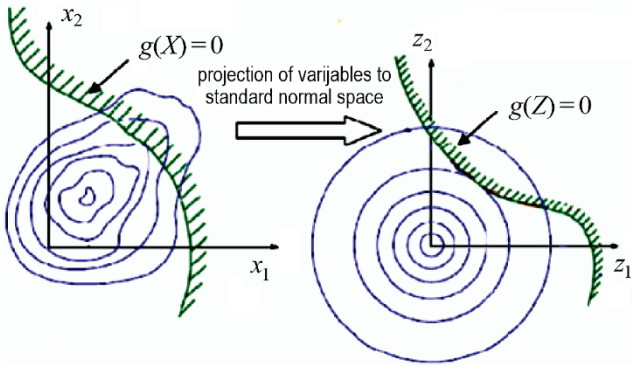

Figure 7 Converting random problem variables to normal space

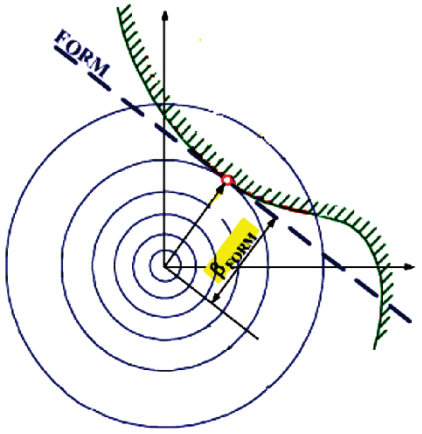

Figure 8 Approximation of F0RM method from the probability of failure

Step 2: The point with the highest probability of failure, Z, that has the shortest distance from the origin of coordinates in Z space is obtained by using suitable nonlinear optimization algorithms. This point is usually called the design point or β point, of which the distance from the origin of coordinates in the normal standard space is called the reliability index, β [14]. This step is shown in Fig. 8.

Step 3: The first-order reliability method of limit state function, $g_z(Z)$, is replaced by a first-order (linear) procedure, $g_L(Z)$, at the design point tangent to $g_z(Z)$.

Step 4: probability of failure, $P(f)$, in the first-order reliability method is obtained as follows.

$$P(f) = P\left[g_L(Z) < 0\right] = \Phi(-\beta) \tag{6}$$

Where, $P(f)$ is probability of failure and Φ is cumulative distribution function for normal standard random variable as follows:

$$\Phi(z) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{z} exp\left(-\frac{1}{2}\alpha^2\right) d\alpha \tag{7}$$

Because the objective is to compare three structural systems, it is sufficient to obtain β index for the three systems and compare them with each other.

7 MODELING SAMPLES AND EXTRACTING RESULTS

To compare two structural systems with dampers and without dampers, initially two types of bending frames and frames with dual systems (bending frame and chevron bracing) were designed by Sap2000 software; TADAS damper was then applied to the frame with dual system at the point of collision of chevron braces (as shown in Fig. 9).

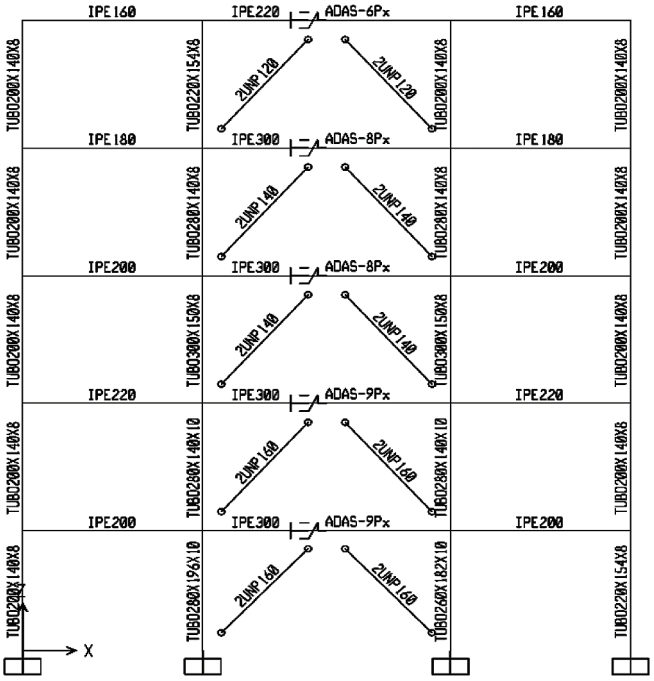

Figure 9 The frame used in the present study

Two random variables, earthquake duration and maximum earthquake acceleration (PGA), were used to model reliability. For this purpose, the models were subjected to accelerograms of important earthquakes such as Bam, Tabas, Kobe, Nordrich, San Fernando and several hypothetical accelerograms (with maximum acceleration and different duration) and structural response (last floor displacement and base shear) was extracted from the models using time history dynamic analysis. Fig. 10 shows Bam earthquake accelerogram as example.

Limit state functions are defined based on roof displacement, controlled by the allowable value, which is equal to values of the regulations. Mathematical formulation of the limit state functions was considered as follows. For the

limit state based on base shear, shear value obtained in section design from static analysis of the structure was considered as allowable base shear (Tab. 2 shows probabilistic characteristics of the random variables).

$$g_1(x) = U_{all} - U_{max} \quad (8)$$

$$g_2(x) = V_{all} - V_{max} \quad (9)$$

Where, U_{max} is maximum roof displacement; V_{max} is maximum base shear; U_{all} is allowable drift value and V_{all} is design base shear.

Using reliability analysis, the results for limit state functions, g_1 and g_2 (Eqs. (8) and (9)), were analyzed and the results of reliability index for the two structures are shown in Tab. 3 and Fig. 11.

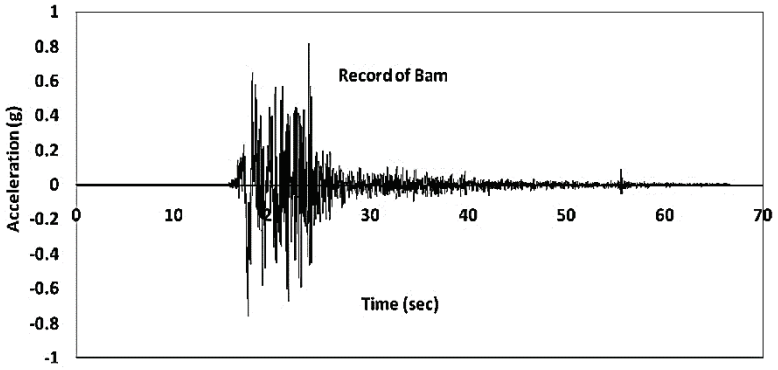

Figure 10 Bam earthquake accelerogram

Table 2 Probabilistic characteristics of random variables

Factor of variation	Mean	Probability distribution	Random variable
0.1	0.48	defined	PGA
0.1	40 s	uniform	Time

Table 3 Reliability index values (β) for three structures

	Rigid frame	Rigid + chevron	Frame with TADAS
Based on last story displacement	4.353	6.081	8.243
Based on base shear	5.245	8.561	9.21

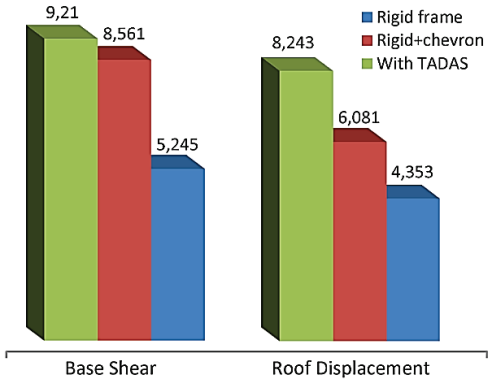

Figure 11 Reliability index values (β) for two types of systems for failure criteria based on roof displacement and base shear

Tab. 3 and Fig. 11 show reliability values for the three frame types based on failure criterion of roof displacement and base shear. Among the three types of frames discussed, the frame with damper in both roof displacement and base shear has the highest value of structural reliability (based on 9.21 base shear and 8.2242 roof displacement). The lowest values of reliability are related to the bending frame (based on 5.245 base shear and 4.353 roof displacement). The braced bending frame has values between the two previous states (based on 8.561 base shear and 6.081 roof displacement).

In general, comparison of three types of frames shows that the damper frame has the best performance and has high reliability, and values of its reliability are very different, especially from values of the bending frame. Despite the fact that the second frame uses two types of bending frame and bracing systems together, its reliability is still lower than the damping frame.

According to Fig. 11, values of reliability based on base shear are higher than the values based on roof displacement in all three types of frames. Therefore, it is reasonable to use floor displacement as a design criterion in order to design with more confidence, so that the design is done based on critical values.

8 CONCLUSION

According to the above, the following results can be extracted:

TADAS metal dampers significantly reduce the values of structural response to earthquakes (in the present study: base shear and roof displacement), which results in better seismic control of the structure.

As discussed in the previous section, dampers used in worn and weak building frames as well as installation in new structures increases structural reliability and consequently, reduces the probability of structural failure and damage; thus, dampers of old structures can be used for improvement of new structures [20].

To determine reliability, different failure criteria must be considered. For structural design, the failure criterion considered should have the lowest values of reliability to design the structure based on critical values.

Many scientists including Sedaghatnezhad, H. et al. [15] in 2022, Houshmand A. [16] in 2021 and Shojaeifar et al. [17] in 2020 studied the seismic behavior of structures equipped with various flowing metal dampers and achieved important results in seismic control of structures using dampers. In the present study, following the previous studies,

reliability was determined by the Monte Carlo simulation method [21], and performance of frames equipped with dampers was evaluated in terms of reliability. Consistent with previous studies, these types of frames have a very good performance in terms of reliability.

Future studies can use more random variables (such as distance and proximity to earthquake faults, ground type, different amounts of damping driving force, application of dampers in different openings and floors, etc.), as well as different failure criteria (including relative roof displacement, floor shear, buckling of columns, etc.) to determine the reliability. By increasing the random variables and failure criteria, the reliability results will be more accurate. To evaluate the reliability of structures equipped with metal dampers, determine the reliability and structural failure, other methods such as system dynamics method [18, 19, 20, 23] can be used instead of the Monte Carlo method. These methods include meta-models such as neural networks, support machines, and kriging.

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Author's contacts:

Parviz Hosseini Sarjou
Department of Civil Engineering,
Higher Educational Complex of Saravan,
Saravan, Iran
ph.sarjou@chmail.ir

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The Correlation between Supply Chain Performance and Information Technology

Mashael Shaye Alghofeli

Abstract: Supply Chain Performance is regarded as a crucial organizational performance indicators. Much effort has been made to enhance it. So, effective and efficient supply chains are recognized as a crucial strategic aspect for achieving several essential corporate objectives, such as improved customer service, enhanced efficiency, and enhanced competitiveness. Therefore, the objective of this study is to analyze the role of information technology on supply chain performance with information technology support as a mediator. The study has been designed based on a descriptive approach using a survey to collect data by questionnaire from Saudi logistics professionals. The potential respondents were members of Hyper Panda's top level of management and executive personnel who were familiar with the company's operations and supply chain procedures. There are 83 valid responses. The research result has several findings and outcomes that will inform future research. The study findings will shed light on choosing the most effective information technology with a significant influence on supply chain performance.

Keywords: information technology; information technology support; PLS-SEM; supply chain performance

1 INTRODUCTION

Information Technology and supply chain performance have recently gotten a considerable amount of attention from academics and practitioners alike [1-3]. Firms that are considering incorporating supply chain management into their current organizational models must also consider the need to apply information technology [4-6]. Organizations using information technology to present and apply their resource arrangement processes gained a competitive advantage over their competitors [3, 7]. It has become increasingly popular to discuss information technology and supply chain management, and there has been an increase in supply chain activity attitudes in organizations to ensure that downstream and upstream events are organized and consistent to make supply chains effective [8-11]. The efficiency of a supply chain is becoming more crucial for the survival of a world-class organization. Many businesses get involved in at least one supply chain. To attain higher results, they must perform equally well. Every organization's lifeblood is information; the modern organization needs accurate, timely, and thorough information [2, 12, 13].

The current period has witnessed radical transformations in IT which directly affected the field of business administration and performing the supply chain. Therefore, business administration specialists must adapt to these rapid changes [14, 15]. Rather, it imposed on the business administration specialist to strive hard towards finding mechanisms and building strategies and keeping pace with every talk in IT to confront these rapid changes, especially with the general trends towards the open market and the entry of competitors from international organizations that have become a direct line for all organizations in chain supply. Many businesses strive to effectively improve their supply chain as well as achieve higher performance. Also, using IT was recognized to have high importance in supply chain management performance (SCMP); a new concept among SCM pears is "digitized SCM performance", That is, conventional supply management activities must be transformed into actions based on information that is integrated and encompass both downstream and upstream activities [16-18]. The fundamental challenge for businesses is identifying how to implement internationalization and supply chain operations successfully [16].

Information Technology plays a significant and vital role in supporting SCM to perform its various functions and activities, whether at the internal level that including operations and activities at the operational level, or the level of external working relationships with suppliers, customers, and stakeholders, depending on the information that allows its flow with the speed, accuracy and time required, besides effective forecasts that raise the efficiency and effectiveness of the company and enhance the performance of its supply networks, hence enhancing the organization's overall performance. The utilization of IT is seen as a precondition for the proper management of today's complicated supply chains [19-22].

Even though supply chain performance is among the vital organizational factors of success, lots of effort is dedicated to enhancing it. However, the systems and tools provided by technologies to the organizations cannot be avoided; these tools help organizations survive in an era of such intense competition. From this point, the research attempted to determine the effect of information technology on enhancing the performance of supply chain at the marketing sector, Hyper Panda, in Jeddah, thereby assisting the marketing sector in developing a road map for implementing and employing the most favorable information technologies to achieve the most desirable performance of supply chain [23-27]. The difficulty with the research was the absence of Arabian sources that emphasize the influence of IT on supply chain performance. A survey of the relevant literature indicated that this topic has neither been thoroughly described nor thoroughly confirmed. Therefore, the main question of the study is:

RQ1: What is the tangible effect of information technology upon the performance of supply chain management?

The purposes of the study are to investigate the relation between information technology and supply chain performance which the study will lead to many findings that will inform future research. Moreover, provide the marketing industry with information on choosing the most effective

information technology with a substantial effect on the performance of supply chain.

2 THEORETICAL BACKGROUND

Supply chain management (SCM) is defined differently by different authors by bringing together stores, suppliers, manufacturers, and warehouses under a single concept, SCM aims to manufacture a product at the right time and distribute it to the right locations in the appropriate quantities to meet the service level demands at the same time as minimizing system costs [19]. Effective supply chain management is crucial in obtaining sustainable growth and growing competitiveness. This is especially true in the case of SMEs, given the intense competition in the current market [13, 27]. To run the supply chain functions of SMEs efficiently and effectively, they need IT for long-term sustainability [8, 9]. Furthermore, IT globalization has enabled new business opportunities to emerge, and SMEs are searching for ways to boost their productivity and become more competitive [5]. Therefore, SMEs are becoming more aware of the potential for profit-making from IT [8]. In former IT investigations [26], it has been shown that only a few SMEs have focused on IT implementation. Despite the proportional development of IT in SMEs, their IT adoption rate is rather low [11], and large businesses have profited more than SMEs from their IT-based marketing strategy in terms of cost savings [12]. As the causes for the disparate adoption of IT in SME enterprises are discussed, the following features of these organizations may be highlighted: Due to their restricted access to market knowledge, SMEs encounter globalization obstacles [23].

That the spread of IT into supply chain operations increases its value-creating potential. In today's cutting-edge enterprises, the capacity to regulate the flow of information is one of the most valuable assets [19]. IT has the capacity to manage the flow and influence many aspects of the supply chain, delivery, including cost, flexibility, quality, and ultimately the firm's profits [9]. IT facilitates collaboration and communication across the supply chain. Ref. [23] emphasized the role of IT in deciding the final success of supply chain management and presented evidence that IT was a prerequisite for the success of the initiatives of supply chain management. Information technology (IT) to manage the supply chain process has gained increasing attention in the business sector. In fact, according to a recent survey by Forrester Research, U.S. manufacturers are increasingly reliant on IT's benefits to enhance supply chain ability, reduce cycle time, increase efficiency, and deliver products to clients on time [24].

2.1 Information Technology

The technical capacity to gather, process, and transmit data to support corporate decision-making and allow communication, coordination, and cooperation across many partners throughout the supply chain is referred to as information technology capability [24]. Successful development of information technology infrastructure paves the way for increased capabilities in information technology [25]. As a consequence, the study found that information technology expertise leads to more effective supply chain integration operations and higher corporate success [23].

2.2 Supply Chain Performance

Supply-chain operations reference (SCOR) is an organized and well-adjusted technique for recognizing, assessing, and monitoring supply chain performance that combines performance indicators, processes, best practices, and people, [21]. It has been vastly used for evaluation and optimization, and it is largely regarded as among the most potent approach for strategic supply chain decision-making. SCOR is the only model applicable to all business sectors that incorporates all sorts of informational, flows physical, and financial and all stages of supply chain maturity intra-organizational to societal [22].

Supply chain performance and good supply chain management are increasingly acknowledged as crucial components in a company's ability to acquire a competitive advantage [18]. Earlier supply chain modeling studies included a variety of performance metrics, including cost, customer response, and activity time [27]. Since it was simpler to apply in quantitative models, most of these studies have focused primarily on cost as the major indicator of supply chain success.

2.3 Performance of Supply Chain and Information Technology

Information Technology underpins supply chain management. They let firms collect, analyze, and distribute data among supply chain players to improve decision-making [5]. We can reduce the temporal and physical distance by bridging functional and organizational barriers and delivering relevant, accurate, and timely information to managers. This allows managers to make more collaborative decisions. Recent technology improvements have significantly boosted businesses' connectivity. The objective of enabling individuals at any point in the chain to engage smoothly is becoming a technical reality [15].

Using information technologies helps organizations stay competitive in a global market and achieve operational success. The drivers for the adoption of information technology are customer satisfaction and time- and cost savings [1]. With the use of information technology (IT), supply chain performance can be improved without affecting business practices and manufacturing operations [8]. As a result of these findings, ICT plays a pivotal role in the transformation of organizations into competitive enterprises [12]. These observations support the subsequent hypothesis:

Hypothesis 1: Information Technology will hold a desirable impact on Supply Chain Performance.

2.4 Information Technology Support

In general, information technology support plays a critical role in helping organizations acquire new competencies and skills that would be hard to acquire without them [4]. Additionally, it facilitates cooperation practices [14] and enables organizations to operate at a higher level of

information processing capability [16]. The importance of information technology support as a critical enabler for SCP implementation [4].

According to [10], information technology investment appears necessary if SCP solutions are scaled up. This is because information technology enables and coordinates SCP using a wide collection of knowledge-based tools and technologies. In addition, it supports efficient information search, access, and retrieval and increases cooperation and communication among organizational members [11]. As a result, it appears as though information technology support mediates the influence of information technology on SCP. As a result, higher information technology support is claimed to have a more decisive impact on SCP. This mediating effect is consistent with the idea that information technology investments boost performance by supporting fundamental competencies [9, 12]. Each component of the SCOR model incorporates these abilities.

These observations support the subsequent hypothesis:

Hypothesis 2: Information Technology will positively affect Information Technology Support.

2.5 Information Technology Support with Supply Chain Performance

Information Technology Systems have been the basis infrastructure of cooperation and competition for contemporary enterprises, and the favorable impacts of IT upon the performance of supply chain have been affirmed by numerous researchers [8,12].

The development of information system support improves the operational performance of businesses in terms of cost savings, improved resource utilization, and enhanced business performance [3]. Information technology improves the operational performance of businesses in terms of customer responsiveness and cost-effectiveness [26]. These observations support the subsequent hypothesis:

Hypothesis 3: Information Technology Support will have a positive effect on Supply Chain Performance.

Hypothesis 3a: Information Technology Support will positively mediate the relationship between Information Technology and Supply Chain Performance.

2.6 Research Model

The research framework in this study is expected to provide an overview and lead to the assumptions of the variables studied that consists of two key variables: the independent variable, supply chain performance, information technology and the dependent variable, which consists of four main dimensions (plan, source, make, and delivery) with information technology support mediating the relationship between information technology and supply chain performance. The research model can be seen below.

3 RESEARCH METHODOLOGY

The methodology describes the actions to be taken when analyzing the relationship between variables of interest. It includes the following steps: the sample, instrument, and procedure.

3.1 Sampling

This study uses nonprobability random sampling. The population of this research was the Hyper-Panda Mall in Jeddah, representing the Saudi Arabian marketing industry. The possible respondents of this survey were members of Hyper Panda's upper and executive personnel who were familiar with the company's activities and supply chain practices. The study sample was recruited using social media. There are 83 valid responses.

3.2 Instrument and Procedure

The questionnaire is made up of two sections. The first section has demographic and other information. The second section related to questions that covered IT [9, 21, 30]. Those inquiries have been made following the analysis of facto. Furthermore, the inquires in the part one is based on a nominal scale. All responses and items reflect over a five-point Likert scale. In the scale one represents firmly disagree and five shows firmly agree.

Smart PLS 3.0 has been utilized to assess the data employing PLS-SEM (partial least squares structural equation modelling) technique [5, 7]. Recently, this method has been considered as an effective means for business-related analyses [22]. In 2 stages, the data have been analyzed and discussed. The PLS technique has been firstly utilized in the measurement pattern to evaluate discriminant validation, internal consistency reliability, as well as convergent validation.

4 RESULTS

According to Fig. 1, the model of the study has two main variables, one is information technology, and the other is supply chain performance consisting of 4 main dimensions (plan, source, make, delivery) that will be measured using the tool suggested by Bronzo et al. [7] with mediating Effect Information Technology support.

4.1 Measurement Model and Descriptive data

As shown in Tab. 1, 83 individuals took part in the present survey, including 85.5% male and 14.5% female, the majority were in the middle age, and two-thirds had bachelor's degrees, the income varied across the category with an advantage of 10-15 thousand Saudi riyals, the participants seem to have good experiences, and 54.2% held manager position.

The relation among the constructs have been substantial and positive. Besides, they were in the range of ($r = 0.898$, $p < 0.01$) and ($r = 0.444$, $p < 0.01$). In order to confirm the validity of discriminate among the latent constructs, the lowest square root of AVE (0.769) was greater than the highest correlation (0.731).

So, to meet the above criteria, 6 indicators were eliminated from the model (IT5), which was deleted due to the low factor loading, and (SSO1), which was deleted to improve the model fit.

The considerable amount of path estimations (β) has been analyzed on the basis of the t value ($p < 0.05$). *R* squared (R^2) is a influence function of the independent variables upon the dependent variable, so R^2 of supply chain efficiency is 0.514, meaning that 51% of the impact done by independent variables (information technology and information technology support). SRMR achieved a good result (0.098). The mean scores of the variables indicated a high level, they ranged between (3.99±0.65/high level) and (3.85±0.68/high level) (See Tab. 2 and 3). So model is accepted for testing the hypotheses.

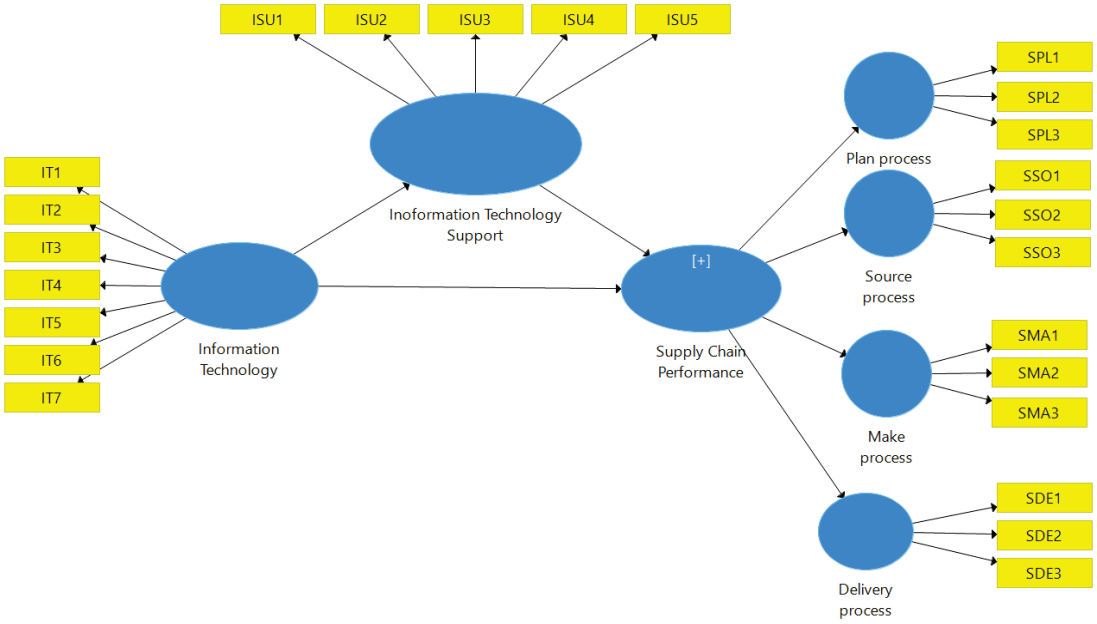

Figure 1 The study framework

Table 1 Descriptive data (N=83)

Variables		N	%
Gender	Female	12	14.5
	Male	71	85.5
Age	20 – 29 years old	19	22.9
	30 – 40 years old	34	41.0
	40 – 50 years old	25	30.1
	50 – 60 years old	4	4.8
	More than 60 years	1	1.2
Education	Secondary school	13	15.7
	Bachelor	62	74.7
	Master	8	9.6
Income	5.000 or below	16	19.3
	5.000 –10.000	12	14.5
	10.000 –15.000	29	34.9
	15.000 –20.000	10	12.0
	20.000 or more	16	19.3
Experience	less than 5	19	22.9
	from 5 to 10	3	3.6
	from11 to 15	19	22.9
	from 16- 20	18	21.7
	more than 20	24	28.9
Position	Administrative	7	8.4
	Chairman of board director	18	21.7
	Manager	45	54.2

The measurement model's validity was assessed by evaluating the discriminant and convergent validity of the constructs. Firstly, convergent validity, construct reliability can be evaluated from the Cronbach's alpha and composite reliability values of constructs. The suggested composite reliability and the Cronbach's alpha value above 0.7 [18, 19]. The outcome of the test of reliability in Tab. 3 demonstrate that all of the constructs hold the Cronbach's alpha and the values of composite reliability are greater that (0.7). Given some studies [12, 21], the average variance extracted (AVE) is more than 0.50 for nearly all of the constructs, demonstrating enough convergence. For a next validation measurement, discriminant validity may be evaluated by making a comparison into relationships among constructs with the square root of the average variance extracted for a construct [22, 23]. Considering Tab. 3, the AVE square root is above the relation with other constructs, indicating sufficient validity of discriminant.

4.2 Hypothesis Analyses and structured Model

Following carrying out validity experiments on the models of measurement, we assessed the structural model.

The hypothesis tests' results are illuminated in Tab. 4.

H1: Information Technology will have a positive effect on Supply Chain Performance.

The structural equation model's outcomes affirmed that the structural path among the constructs has been substantial ($\beta = 0.164$, $t = 2.652$, $p = 0.008 < 0.005$). **Thus, H1 is confirmed.**

Hypothesis 2: Information Technology will positively affect Information Technology Support.

The structural equation model's result confirmed that the structural path among the constructs has been remarkably positive ($\beta = 0.541$, $t = 5.983$, $p = 0.000 < 0.005$). Consequently, **H2 is confirmed.**

Hypothesis 3: Information Technology Support will have a positive effect on Supply Chain Performance

The structural equation model's outcomes confirmed that the structural path among the constructs has been substantially positive (β = 0.273, t = 4.062, p = 0.000 < 0.005). As a result, **H3 is fulfilled.**

Hypothesis 3a: Information Technology Support will positively mediate the relationship between Information Technology and Supply Chain Performance.

The result of structural equation modelling approved that Information Technology Support statistically mediate the relationship between Information Technology and Supply Chain Performance (β = 0.245, t = 3.160, p = 0.000 < 0.005), the mediation is supported. Thus, **H4 is supported.**

Table 2 Factors' loading (N = 8)

Constructs	Indicator	VIF	Information technology	IT support	Delivery process	Make process	Plan process	Source process
IT support	ISU1	2.035	0.801					
	ISU2	2.206	0.831					
	ISU3	2.201	0.818					
	ISU4	2.369	0.865					
	ISU5	1.692	0.753					
Information technology	IT1	1.949		0.704				
	IT2	2.419		0.814				
	IT3	1.834		0.741				
	IT4	1.804		0.804				
	IT6	2.105		0.809				
	IT7	2.548		0.760				
Delivery process	SDE1	2.009			0.869			
	SDE2	2.363			0.896			
	SDE3	2.009			0.869			
Make process	SMA1	2.260				0.883		
	SMA2	2.112				0.871		
	SMA3	2.739				0.916		
Plan process	SPL1	2.746					0.913	
	SPL2	1.892					0.861	
	SPL3	2.116					0.853	
Source process	SSO1	1.337						0.878
	SSO2	1.696						0.854

Table 3 CR, AVE, α, √AVE , R^2 and Relation among variables

Construct	M±SD	Cronbach's Alpha	Composite Reliability	Average Variance Extracted (AVE)	R square (R^2)	Delivery process	IT Support	Information Technology	Make process	Plan process	Source process	Supply Chain Performance
Delivery process	3.78±0.70	0.85	0.91	0.77	0.807	**0.878**						
IT Support	3.99±0.65	0.85	0.90	0.60	0.351	0.609	**0.773**					
Information Technology	3.85±0.68	0.87	0.89	0.67	--	0.659	0.592	**0.815**				
Make process	3.76±0.75	0.87	0.92	0.79	0.761	0.634	0.444	0.457	**0.890**			
Plan process	3.84±0.71	0.85	0.91	0.77	0.671	0.741	0.630	0.572	0.643	**0.876**		
Source process	3.87±0.62	0.77	0.86	0.75	0.703	0.670	0.574	0.622	0.617	0.731	**0.866**	
Supply Chain Performance	3.76±0.63	0.90	0.92	0.59	0.514	0.898	0.618	0.659	0.872	0.819	0.839	**0.769**
SRMR=0.098												

Table 4 Results of Hypotheses Testing

Relationship	Std. β	t	p	Decision
Hypothesis 1: Information Technology has a desirable impact on Supply Chain Performance	0.164	2.652**	0.008	Supported
Hypothesis 2: Information Technology will positively affect Information Technology Support.	0.541	5.983***	0.000	Supported
Hypothesis 3: Information Technology Support has a desirable impact on Supply Chain Performance	0.273	4.062***	0.000	Supported
Hypothesis 3a: Information Technology Support will positively mediate the relation between Supply Chain Performance and Information Technology.	0.245	3.160***	0.000	Supported mediation
*$p \leq 0.05$; **$p \leq 0.01$; ***$p \leq 0.001$				

5 DISCUSSION

The study aimed to define the relationship between information technology and supply chain performance, emphasizing the moderating effects of information technology support. To achieve this goal, the researcher developed a questionnaire and distributed it to a sample of employees from the top-level management or executive staff of Hyper Panda in Jeddah

Consequently, eighty three questionnaires have been returned in a successful manner. Following gathering information, the validity of reliability and testing measurement took place via EFA. After that, the data was analyzed with the aid of Smart-PLS version 3.0 and SEM. The significance of SEM is rooted in the reality that several indices could be included in the hypothesized models, its validity of the latest model analyzed, and the simultaneous test of the independent elements' prediction on dependent variables.

As mentioned in the study model, it comprises 2 main variables, with information technology as the independent variable. The dependent variable is supply chain performance, consisting of four key aspects (plan, source, make, and delivery). It will be assessed employing the instrument put forward by Bronzo et al. [7], with Information Technology support serving as mediator. That study indicates that information technology could supply value. That affirms the RBV theory that common technology may transform into valuable resources by deploying processes. Therefore, our findings imply that it is beneficial to monitor intermediate information technology support and investigate how information technology support can enhance organizational operations for the information technology and supply chain performance.

As shown in Tab. 4, all four hypotheses were significant. A key of operational effectiveness is information technology, which enables supply chain performance competitive benefit, which quickens more desirable supplier and customer interaction. The result of structural equation modelling confirmed that the structural path among the constructs has not been substantial ($\beta = 0.164$, $t = 2.652$, $p = 0.008 < 0.005$). Hence, H1 is supported and [18] also proved that this hypothesis is confirmed.

According to Information Technology will positively affect Information Technology Support, the outcome of structural equation modelling affirmed that the structural path among the constructs has been substantially positive ($\beta = 0.541$, $t = 5.983$, $p = 0.000 < 0.005$). As a result, H2 is confirmed, this result was proved in the previous study [24, 4].

This research also examined the mediating effects of information technology support. Results reveal that supply chain competencies can increase the value of information technology related resources for a company. Also, by integrating information technology into a company's supply chain system, the company is able to increase assets through effective information interchange and improved supply chain partner coordination. In addition, higher levels of information technology support between supply chain processes were shown to be related to a stronger favorable relationship between information technology and supply chain performance. This was consistent with earlier results regarding the critical enabling function of information technology support and the influence on performance through bolstering core capabilities.

6 CONCLUSION

The research examines the role of information technology support between information technology and supply chain performance. We have conducted field research in 2022 on a cross-sectional sample of Saudi logistics professionals. The potential respondents were members of Hyper Panda's top level of management and executive personnel who were familiar with the company's operations and supply chain procedures. In order to conduct the field research, a structured questionnaire was developed using several criteria from previous empirical studies. As a result of the study, empirical evidence is provided that information technology support affects supply chain performance and highlights the positive and significant relationships between information technology and supply chain performance. In the future, our conceptual framework may be replicated in other Saudi Arabian regions, which could help us compare our findings with the present research. The impact of information technology on supply chain processes throughout the organization is also important. It will be interesting to investigate the role of knowledge technology support in the relationship between supply chain performance and information technology.

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Author's contacts:

Mashael Shaye Alghofeli
Faculty of Economics and Administration,
King Abdulaziz University,
Jeddah, Kingdom of Saudi Arabia
E-mail: alghofeli@hotmail.com

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Technical and User-Oriented Prerequisites for Video CV Web-Based Recruitment Platform

Davorin Turkalj*, Antun Biloš, Marija Šmit

Abstract: Youth unemployment tends to be higher than in other age groups mainly because young people represent an inexperienced labour force. Some authors also believe it is due to an inability to match the qualified workforce to vacant positions. The importance of enabling young people to participate equally in the labour market is of the essence for economic growth. One of the attempts to tackle this issue was addressed through the Erasmus+ project CUVID, aimed at providing young people a way to present themselves in video-based form. This paper analyses quality standards for video CV platforms. For this purpose, 19 expert interviews with HR managers were conducted to identify their expectations towards video CVs. Based on the analysis of expert interviews, a recommendations summary with technical and user-oriented prerequisites was created, along with requirements and a transferability model for video CVs in the form of the CUVID platform.

Keywords: employment; labour market; recruitment; video CV; web platform

1 INTRODUCTION

A growing concern of high unemployment rates among young people in the EU has been addressed in many scientific papers as well as in media and daily conversation. According to the Eurostat [1], in the year 2021, around 5 million young people (aged 15-29 years) were unemployed in the EU. The main reasons for this high number could be attributed to lack of experience or adequate qualification after young people finish their formal education and enter the labour market. Some authors also state that there is a recorded deviation or inability to match the availability of young workforce and vacant positions [2].

As Generation Y has grown up with the internet, they are tech-savvy and are actively searching for jobs in the job market. This factor prompts them to apply through online recruitment, either through job portals or the company website [3]. A habit of daily interaction between humans and a wide range of online services raises the question of why aren't all segments of life covered by this wave of digitalization. One of the areas that remains almost the same is the process of reviewing a job application. The most common way of applying for a job is to provide a written resume that contains all the essential personal information, qualifications, and skills that could help an HR manager to make an educated decision about a job candidate. Curriculum vitae or CV is a short account of one's career and qualifications prepared typically by an applicant for a position [4].

A video CV, as opposed to a traditional, written resume, provides a more in-depth overview of the applicant's personality traits and communication skills, both of which are highly valued in today's business [5, 6]. HR departments adopted new recruitment practices as remote work became more common following the coronavirus pandemic crisis. Among these practices are video interviews, which provide a better overview during the recruitment assessment stage [7, 8]. Employers must have a streamlined recruitment and selection process to gain objective insight into applicants' formal and other achievements [9].

Implementing other forms of evaluation or digital presentation of personal academic or other relevant achievements is not a novel practice for tech companies and digital natives but rather a widely spread practice [10]. Employers have been screening potential employees' online activities since the advent of social media. The issue arises when job applicants fail to consider their digital social accounts as a potential source of information for future employers. Businesses are abandoning measuring applicants' institutional appropriateness by forming opinions based on information from social media profiles as awareness of privacy and discriminatory concerns grow [11, 12]. It is expected to meet those needs and trends by providing a more comprehensive revision of the traditional approach to job application through the development of an adequate tool for presenting an online resume. For this purpose, a video presentation would be the best option.

The Europe 2020 strategy focused on promoting economic growth through one of its flagships, The Youth on the Move. This flagship aims to enhance the performance and quality of the education and training systems, promote youth mobility, both for learning and work purposes, ensure a smooth and speedy labour market transition of young people, and reinforce the international attractiveness of Europe's higher education [13, 14]. As a response to the Europe 2020 strategy, the CUVID (CUrriculum VIDeo) project was applied and approved. The project was co-funded by the Erasmus+ Programme of the European Union. Europe continued making youth unemployment its priority by adopting Youth Employment Support in 2020. Key actions include broadening young people's age group from 15 to 29 year-olds (previously 15-24), being more inclusive to avoid any forms of discrimination, and being more future-proof to profit from the digital and green transitions [15].

Fostering employment and social inclusion of young Europeans is at the heart of the CUVID project. While young graduates from academia also suffer from high unemployment, VET (Vocational education and training) graduates encounter even more difficulties finding (first) employment. For that reason, project focuses primarily on VET students and teachers. The objective of CUVID is to

enable young people to present themselves and their skills to potential employers most beneficially and effectively. With this project, young people will not only be motivated to use a new application method but will also be able to gain skills in video production, job application methods, and self-presentation that they can also transfer and benefit from in other contexts. The task for the partners involved in the CUVID project was to develop a web-based platform designed to provide a solution for video CV presentations.

This paper aims to provide a gap analysis by conducting interviews with HR experts to obtain recommendations from their perspective, clarify their expectations and special needs, create tailor-made videos CV platform, and identify specific problems and challenges with regard to video-based application processes and forms.

2 METHODOLOGY

Semi-structured expert interviews were conducted to define the technical and user-oriented prerequisites for developing a video-based CV web platform. As a part of a more extensive research, expert interviews with 19 heads of companies or HR experts were carried out. The goal was to establish how they would perceive and rate the introduction of a video CV platform as a new or alternative way of evaluating applicants for a specific job position, as well as their perspectives on the benefits and potential drawbacks of such a platform. Results provided in-depth qualitative insight that contributed to the extraction of conclusions and guidelines in the later stages of the project.

Interviews were carried out as a part of the Erasmus+ project with companies that fulfilled predefined criteria in partner countries: Austria, Croatia, the Czech Republic, and Portugal. The CAWI method was applied during the interviewing process. This considers the use of computers for recording, following guidelines, and presenting mock-ups and sketches of existing video CV platforms.

Table 1 List of anonymised interview participants with company description

ID	Country	Industry/Sector	Employees
P1a	Austria	Metal industry	1050
P1b	Austria	Automotive industry	6500
P2a	Portugal	Specialized Retail	1200
P2b	Portugal	Training and consulting	17
P2c	Portugal	Plastic industry	220
P2d	Portugal	Vocational training	20
P2e	Portugal	IT Company	140
P2f	Portugal	IT Company	35
P3a	Croatia	Chemical industry	861
P3b	Croatia	Agriculture	1620
P3c	Croatia	Construction	440
P3d	Croatia	IT Company	50
P4a	Austria	Hotel industry	340
P4b	Austria	Automotive industry	3500
P5a	Czech Republic	Health service	840
P5b	Czech Republic	Automotive industry	520
P5c	Czech Republic	Machinery	10
P5d	Czech Republic	Health / fitness	10
P5e	Czech Republic	Automotive industry	570

2.1 Sampling

Purposive sampling, which is common in qualitative research, was applied. The project proposal predetermined the size of the sample. The selection of the companies and their representatives was based on characteristics relevant to the study. Criteria for choosing the interview candidates:

1) Local companies in all consortium countries that have employed at least ten vocational occupations through the job application process in the last three years, and
2) Companies that have implemented customized software for the business optimization process.

Both criteria had to be met in the process of interview candidates' selection.

3 RESULTS

Results are divided into five distinct segments: gap analysis, expectation/needs, advantages, obstacles, and recommendations. These segments include semi-structured open-ended questions presented and elaborated to the interview participant by one of the representatives of the projects partner country. The outcome presentation only includes the most pertinent elements for debate.

3.1 Gap Analysis

In this segment, the intention was to determine the standard procedures for evaluating job applications. All interviewed companies have developed their own standardized evaluation and employment process.

"We have our own evaluation process based on common and professional standards" – P5a

The procedure usually starts when a need for a specific work position is detected. After that, the company advertises job requirements on a platform of choice: press media, radio, websites, job offer portals, local web portals, social networks, recruiting centres, and in a few cases, Labour market service. The most common are three rounds of evaluations. Starting with preselection – elimination of applications that do not meet job requirements, after which follows a personal meeting with the HR officer or commission where testing for a job occurs, and the latest round is a final interview with the board members and or head of the department requesting a job opening.

A significant difference is detected between large and small interviewed companies. Larger companies tend to receive a large number of applications per job vacancy. Hence, they needed to develop a more structured way to manage all the applications through a digitalized database which they also consult in future job offerings. In contrast, small companies have fewer candidates, so they invest their time in evaluating them more closely. Interestingly, most of the interviewed companies are not using or are not satisfied with the local Labour market service and mostly rely on their own communication channels (paid, owned, or earned) with the labour market.

With regard to how they see that the current application process can be improved, interviewed companies can be divided into two broad groups: those that are satisfied with the current application process and the ones that see room for improvement. Out of 19 respondents, 7 or 36,8% are satisfied with the current state, and 12 or 63,2% of interviewees would like to implement innovations based on experience.

When asked where they see added value in the introduction of video CV applications, 7 out of 19 interviewed companies did not see the added value. The main reasons stated were that the video CV application form is almost unknown to them and that there is a potential danger of discrimination. Also, it would present a certain difficulty when searching specific keywords within a video, unlike in a written form, and uncertainty about whether the candidates would feel comfortable with the video presentation.

"In my experience, I can say that I have not seen any tool that is really helpful in improving the selection process" – P1b

On the other hand, 12 out of 19 interviewed companies, or 63,2 %, see added value in Video CV format. They state that the first impression is essential in detecting desirable characteristics; it makes the selection process faster in the early stages, and it is easier to estimate if the person is truthful and motivated. It also helps centralize the applicant database, encourages creativity, shows that the applicant is interested in the position, and shows information beyond the capabilities of traditional CVs.

3.2 Expectations/Needs

The most common needs specified in the process of traditional (paper) CV applications amongst interviewed companies are the need for more space for personal expression and the difficulty of examining soft skills in written CV form. Additionally, some participants stated that the importance of motivational letters is underestimated as it covers three essential issues: why me; why this company; and why this job position. Also, it is a great way to differentiate yourself from other competitors when similar qualifications or work experiences are compared. Proof of formal education is something that needs to be added to job applications when it comes to applicants with a lower level of education or qualification. Also, it would be nice to have a chance to update or correct CVs once it has already been submitted.

"More space for personal expression" – P5c

"…it would be useful to have a verification on declared information (diplomas, recommendations...) ". – P5e

3.3 Advantages

Only one of the participants sees no direct advantages of using CV video application in terms of making their job more efficient. The rest of the participants highlighted speeding up the preselection process, saving time and money by streamlining the process, making the evaluation process more collaborative, centralized tracking, consistency in the application of specific criteria, more in-depth way to evaluate candidates, and getting more information than they usually would from a written application and thus making decisions about candidates easier.

"Bringing useful information in one-minute sequence…" – P5c

"If there would be a complete package, everything standardized – then it might help save time." – P4b

3.4 Obstacles

When asked if participants could identify any specific problems and challenges considering video-based application processes and forms, they responded that it could affect how candidates are perceived if they don't feel comfortable in front of the camera. As previously mentioned, it could raise some discrimination issues. Furthermore, integration with the current recruitment system could be difficult, and problems with candidates not using appropriate/suggested technology and the security conditions for content privacy are not guaranteed. Today's social network platforms largely depend on popularity and the number of registered users, so that could be an issue in the case of the CV video platform. Also, it would be unfair for the candidates that do not have access to the required technology to be excluded from the evaluation. Smaller companies are happy when they get any applicants, so if there is a prerequisite of sending a video for a job position, they could get even less. They see this type of presentation suitable only for some job positions.

"We see your idea of connecting companies and applicants in this virtual marketplace as a long-term process that needs to take many details into account" – P4b

Interviewed companies state that the reasons for rejecting an applicant's resume or portfolio in video format would be the same as for a written CV – if the candidates do not meet previously defined and posted requirements. A lack of communication capacity would put off a certain number of companies if the competencies do not match the job description. Such practices would include below average presentation of content and frivolous approach to profile or video creation. Affectation, pretence (acting) and making the video look like an advertisement would also be seen as reasons for rejecting the application.

3.5 Recommendations

Almost all interviewed participants would consider implementing a video CV platform in the future. Some would like to try it out of curiosity, some for experimental purposes, and as an opportunity to re-evaluate and upgrade the current recruitment system.

"If it works efficiently and does not imply a massive additional effort to forward a Video CV internally to a department manager (maybe by using a link) then it is a professional tool with added value." – P1b

Participants see benefits such as time-saving, the chance to evaluate candidates' character and appearance, and an opportunity to generate an additional pool of applicants that they could use in search of a perfect candidate for open positions in the future. Participants were mostly unified when providing general tips for potential applicants concerning

presentation tips, dress code, amount of information to provide, etc. The gathered statements are presented in Tab. 2.

Table 2 General tips for potential applicants – as provided by interview participants

Presentation tip	Introduce yourself
	Past job experiences
	What job position are you applying to
	How can you contribute
	What are your expectations
	Objective, concise and professional communication
	What differentiates you from others
	Provide easily proven information
	Take time to make the video personal
	Inform yourself about the company
	Highlight your best features
	Tell only information relevant to the applied position
	Appear authentic
	Relaxed presentation
Dress code	Adequate for the job position
	Clean and respected look
Amount of information	Short video
	1 – 1,5 minutes
	less is more

3.6 Video CV Platform Features

In this section, participants defined the criteria concerning quality and applicability as well as rated the importance of video and sound quality when evaluating the applicants' video CVs. On average, participants preferred that applicants upload short versions of video CVs that would last up to 138 sec on average and 175 sec for the extended video CV version. They expect the video and sound to be clear and understandable.

Tab. 3 shows the selection of relevant services and technical assets that participants chose based on their preferences. These services include geo-positioning of applicants, webcam interviews, social network presence – LinkedIn, Facebook, the possibility of transfer of CV profiles from other social platforms, past work presentations, awards, diplomas, recommendations, standard CV in PDF etc.)

Participant recommendations also included: timeline of application status (accepted, rejected, under consideration), dashboard with analytical capabilities, drop-down menu for job categories when conducting a search, candidate status (unemployed, employed, between jobs).

Companies expect applicants to emphasize the following elements in their video CV: education and work experience in detail, career breaks, and hobbies or interests if there is enough time on the video pitch. Also, they have pointed out that there should be two versions of video CVs, short and extended video versions. A short video CV version should contain answers to the questions: who am I; what are my competencies; what are my strengths; what are my weaknesses and why this job position. Extended video CV version should be used for presenting values that correspond with the company culture, readiness to be a part of the team, and skill demonstration, e.g., for a cook apprentice, a video would be done in the kitchen. Certainly, it would be desirable to see what distinguishes them from the competition. Companies usually expect a customized video for a specific job position because it shows effort and engagement.

Table 3 Additional services and assets companies would prefer on Video CV platform

ID	Geo positioning	Web cam interview	Social network presence	Awards, diplomas, etc.	Standard CV in .pdf
P1a	X	X			X
P1b	X	X			X
P2a		X		X	X
P2b		X	X		X
P2c	X				X
P2d		X	X	X	X
P2e	N/A				
P2f	N/A				
P3a	X	X		X	X
P3b	X	X	X	X	X
P3c	X	X	X	X	X
P3d	X	X	X	X	X
P4a	-				
P4b	-				
P5a	-				
P5b		X	X	X	X
P5c	X			X	X
P5d			X	X	X
P5e	X		X	X	X

According to the participants, the most prominent place of the applicants' profile should be used for presenting the most important information such as name, age, vocational or academic degree, address, and work experience. Companies would be interested to see the profile picture and the job position the applicant is applying for.

As expected, most participants count on the possibility of interacting with their applicants via e-mail (Tab. 4.). Although they like private messaging and push notification options, most interesting information is that they would continue or would like to use the phone for contacting their applicants.

Table 4 Preferred ways of interacting with the potential job applicants

E-Mail	Private Message	Push Notifications	Phone Call
X11 (58%)	X6 (32%)	X7 (37%)	X8 (42%)

3.7 Limitations

Although much attention was given to the selection of interview candidates, a small sample size, typical of qualitative studies, limits the generalizations and external validity of the findings. Also, geographical distance between partner countries proposes a different starting point when choosing between potential interview candidates depending on the availability of companies in the area that are relevant to this research. As this qualitative research is exploratory in nature, it covered the main aspects of the topic and addressed the most prominent research issues.

4 CONCLUSION

All interviewed companies have developed their own standardized evaluation and employment process. The significant difference between interviewed companies is

between large and small companies. Larger companies tend to receive a large number of applications per job vacancy. Hence, they needed to develop a more structured way to manage all the applications through a digitalized database which they would also consult in future job offerings. In contrast, small companies do not have that many candidates, so they invest their time to evaluate them more closely.

Companies are most concerned that a video CV is not a widely accepted job application format. There is a specific need for a solution to minimize companies' concerns when presenting the added value of video CV vs. standard application. Furthermore, there is a potential danger of discrimination, difficulty in searching specific keywords as it is possible in written form, and uncertainty on whether the candidates feel comfortable about video presentation. These identified problems can be tackled by implementing an awareness program among concerned parties, which is already a part of the CUVID project proposal. By providing video tutorials, candidates are instructed on how to perform in front of the camera, thus making them more comfortable in such situations. In addition, it should be considered that the video CV platform should have some key word search capabilities.

Some participants stated that video presentation is more suitable for some job positions and less for others. For that reason, video tutorials should suggest how all candidates, regardless of their vocational orientation, could utilize video CV presentations for their benefit. Only one of the participants does not see any direct advantages of using CV video application to make their job more efficient. The rest of the interviewees highlighted: speeding up the preselection process, saving time and money by streamlining the process, making the evaluating process more collaborative, centralized tracking, consistency in the application of specific criteria, more in-depth way to evaluate candidates, and getting more information than from a written application thus making decisions about candidates easier. The major obstacles identified by interviewed participants were the difficulty of integrating with the current recruitment system, problems with candidates not using appropriate/suggested technology, and the security conditions for content privacy are not guaranteed. Also, they can see that this type of presentation suitable for some job positions but only for some. In most cases, reasons for rejecting a video CV application would be the same as for a written CV – if the candidates do not meet previously defined and posted requirements.

The data collected through expert interviews served as guidelines for the design model based on which a web platform for video CV presentation was created within the CUVID project approved by the Erasmus+ program. This model can serve as a simulation or a blueprint for interested parties looking to implement a more efficient solution for the e-recruitment process. The practical implication of the work stems from identifying technical elements that, in a practical sense, contribute to the functionality and good user experience of jobseekers and employers in the labour market. The economic contribution is reflected in HR experts' confirmation that the web platform for video resumes would help them solve the organizational issues surrounding the recruitment process, increase the business's digital presence and more efficiently find the right person for the vacant position.

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Authors' contacts:

Davorin Turkalj, Associate Professor
(Corresponding author)
Faculty of Economics Osijek
Gajev trg 7, 31000 Osijek, Croatia
davorin.turkalj@efos.hr

Antun Biloš, Associate Professor
Faculty of Economics Osijek
Gajev trg 7, 31000 Osijek, Croatia
antun.bilos@efos.hr

Marija Šmit, PhD
Centar tehnike LTD.
Županijska 31, 31000 Osijek, Croatia
marija.jelic.smit@gmail.com

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Hybrids of Uniform Test and Sequential Uniform Designs with "Intersection" Method for Multi-objective Optimization

Maosheng Zheng*, Haipeng Teng, Yi Wang

Abstract: For multi-objective optimization under condition of complicated objective function, the data processing in the evaluation is sometime tediously long, special algorithm is needed to be adopted. Since the remarkable features of uniform distribution of test points within the test domain and the small number of tests, fully representative of each point, and easy to perform regression analysis, the uniform test design method is hybrid with the "intersection" method for multi-objective optimization to simplify the complicated data process in evaluation first. Furthermore, the "intersection" multi-objective optimization methodology is combined with sequential uniform design so as to get a more precise approximation for solving multi-objective optimization problem, the procedure for searching optimum of the "intersection" multi-objective optimization methodology with sequential uniform design algorithm is put forward. A multi-objective optimization of linear programming problem with three variables is taken as our example, which involves a maximum for one objective and a minimum for another objective. The result for applying the novel approach to the example indicates the effectiveness of current hybrids.

Keywords: hybrid; "intersection" multi-objective optimization; sequential uniform design; simplification in evaluation; uniform test design method

1 INTRODUCTION

Multi-objective optimization is a perpetual project in daily life and practical industry production, which ranges almost all fields. It likely involves several performances or attributes which must be simultaneously considered in the analysis. An appropriately recommended alternative is an optimal one that needs to meet requirement of compromised optimization of various response variables (performances) simultaneously, they are even conflicting each other. Various techniques have been proposed, which include the technique for order preference by similarity to ideal solution (TOPSIS), VIšekriterijumsko KOmpromisno Rangiranje (VIKOR), multi attribute decision-making (MADM), Analytical Hierarchy Process (AHP) and Multi-objective Optimization based on Ratio Analysis (MOORA), etc. [1]. The inherent problems of "additive" algorithm and personal / subjective factors in the above multi-object optimizations make them puzzled [1].

Recently, a new approach named "intersection" method for multi-objective optimization was proposed in the viewpoints of probability theory [1]. It tries to overcome the shortcomings of personal and subjective factors in the above multi-object optimizations by introducing a new idea of favorable probability and the corresponding assessment. The favorable probability is used to reflect the favorable degree of the candidate in the optimization, all performance utility indicators of candidates are divided into beneficial or unbeneficial types according to their features in the selection, and each performance utility indicator of the candidate contributes to a partial favorable probability quantitatively; the total favorable probability is the product of all partial favorable probabilities in the viewpoints of probability theory and "intersection" of set theory, which is the overall consideration owing to the compromised optimization of various response variables simultaneously; the total favorable probability is the unique decisive index in the competitive selection process. Appropriate achievements have been obtained [1].

In general [2, 3], the difficulty in solving the multi-objective optimization problem is due to the complexity of the multi-objective optimization problem itself. The primary problem of multi-objective optimization is to generate a subset of non-inferior solutions, and then find the final ideal and effective solution from it according to the intention of the decision maker. There are three main types of methods to find the final solution: a) Generative method, which first finds a large number of non-inferior solutions to form a subset of non-inferior solutions, and then finds the final solution according to the intention of the decision maker; b) Interactive method, which does not need to find a lot of non-inferior solutions first, but gradually find the final solution through dialogue between the analyst and the decision-maker; c) Request the decision-maker to provide the relative importance of the goals in advance, and use this as a basis to combine multiple goals. The problem is converted to a single objective problem to be solved. These are mainly achieved through algorithms. Many experts and scholars have used different algorithms to solve multi-objective optimization problems, such as multi-objective evolutionary algorithm, multi-objective particle swarm algorithm and ant colony algorithm, simulated annealing algorithm and artificial immune system. It indicates that more serious algorithms are involved in the solving of multi-objective optimization problem [2, 3].

In 1978, Fang and Wang developed a novel type of experimental design that is known as uniform design [4, 5]. Since the remarkable features of uniform distribution of test points within the test domain and the small number of tests, fully representative of each point, and easy to perform regression analysis, this method had been successfully applied to the design of Chinese missiles [4, 5].

After their articles were published in the early 1980s, uniform design has been widely applied in China and has gotten great achievements [4, 5].

Uniform design belongs to the quasi-Monte Carlo methods or number theoretical methods. In optimization process, as the calculation of a single variable problem is generalized to a multivariable problem, the increase of

calculation complexity is increase obviously with the number of variables; as to multi – objective optimization, the increase of complexity in assessment is more serious. Even with the great advances in computational technology, the complexity is still there. Monte Carlo method (i.e., statistical stimulation) is to transfer an analysis problem into a probability problem with the same solution, which use a statistical simulation to deal with the probability problem. This solves some difficulty in analysis of assessment, including the approximate calculation of multiple definite integrals [4-6].

While, the sequential number theory optimization (SNTO) was introduced into the uniform experimental design as a new global optimization approach [7-11].

It seeks for the global extreme value among uniformly distributed points in the space of variables, and the convergence is speeded up by contracting the searching space. In each search only the points close to the extreme value (minimum or maximum) function value are retained among the uniformly scattered points. In order to get the global optimum properly one needs to choose the sufficient number of points for the first search [7-11].

As stated in [7], if $l(D)$ is used to indicate the length of largest edge of the rectangle domain D. Assume that one can find a domain D^* such that $x^* \in D^* \in D$ and $l(D^*) << l(D)$, then the optimization problem of $M = Maxf(x^*)$ for all $x \in D$ (in domain D) is reduced to an optimization problem in the region D^*, and thus the same sized NT-net could lead to a much more precise approximation to x^* normally. This idea was initiated by Niederreiter and Peart in 1986 and by Fang and Wang in 1990 [7]. More precisely, a sequential algorithm for optimization (SNTO) with NT-nets was suggested by Fang and Wang [7]. This method has been used in solving optimum problem with single objective [7-11].

In this paper, a hybrid of uniform test design method with the new "intersection" method for multi-objective optimization is developed to simplify the complicated data process in evaluation first. Then the new "intersection" multi-objective optimization method is combined with sequential uniform design to get a more precise approximation for solving multi-objective optimization problem.

2 PROCEDURES OF HYBRIDS OF THE "INTERSECTION" METHOD FOR MULTI-OBJECTIVE OPTIMIZATION WITH UNIFORM TEST DESIGNS

2.1 Hybrid of "Intersection" Method for Multi-objective Optimization with Uniform Test Design

The remarkable features of the uniform test design (UTD) includes, uniformly distributed "representative points" of designed tests with deterministic positions within the domain of variables, small number of designed tests to reflect the whole feature of the responses within the domain of variables, and fully representative of each point. So the UTD method can be used to get a hybrid with the "intersection" method for multi-objective optimization to simplify the complicated data process in evaluation.

Additionally, in the "intersection" method for multi-objective optimization, the total favorable probability is the unique and decisive indicator of the alternative; therefore, the final assessment including regression analysis should be focused on this determinant indicator with limited number of discrete test points by means of uniform test design.

2.2 Hybrid of Intersection Method for Multi-objective Optimization with Sequential Uniform Design

In reference to the procedure proposed by Fang and Wang for sequential algorithm for optimization (SNTO) with NT-nets [7-11], we could develop the operation process for the combination of sequential uniform design with the "intersection" method for multi-objective optimization.

If SNTO for D being a rectangle [$\boldsymbol{a}$, $\boldsymbol{b}$]. In our case, the maximum value of total favorable probability P_t is assessed for the point set in each step. Thus, the operation process of SNTO algorithm for combination of sequential uniform design with "intersection" method for multi-objective optimization is as follows:

0th Step: Initialization.

At moment $t = 0$, $D^{(O)} = D$, $\boldsymbol{a}^{(O)} = \boldsymbol{a}$ and $\boldsymbol{b}^{(O)} = \boldsymbol{b}$.

1st Step: Generate an NT - net.

Number-theoretic method is used to generate a n_t points $\boldsymbol{P}^{(t)}$ uniformly distributed on $D^{(t)} = [\boldsymbol{a}^{(t)}, \boldsymbol{b}^{(t)}]$. $P_t(\boldsymbol{x}^{(t)})$ is the maximum value of total favorable probability at moment t of the alternative in the point set.

2nd Step: Calculate a novel approximate value.

Assume $\boldsymbol{x}^{(t)} \in G^{(t)} \cup \{\boldsymbol{x}^{(t-1)}\}$ and $M^{(t)}$ such that $M^{(t)} = P_t(\boldsymbol{x}^{(t)}) \le P_t(\boldsymbol{y})$ for number of points with characteristic of $n_{t-1} = n_t = \ldots$, $\forall \boldsymbol{y} \in G^{(t)} \cup \{\boldsymbol{x}^{(t-1)}\}$, where $\boldsymbol{x}^{(-1)}$ is the empty set, $\boldsymbol{x}^{(t)}$ and $M^{(t)}$ are the best approximations to $\boldsymbol{x}^*$ and M temporarily.

3rd Step: Termination condition.

Let $c^{(t)} = (P_t^{(t)} - P_t^{(t-1)})/P_t^{(t-1)}$. If Max $c^{(t)} < \delta$, a pre-assigned small number, then $x^{(t)}$ and $M^{(t)}$ are acceptable; terminate algorithm. Otherwise, proceed to next step.

4th Step: Domain contraction.

A new domain is formed like this: $D(t+1) = [\boldsymbol{a}^{(t+1)}, \boldsymbol{b}^{(t+1)}]$ as follows: $a_i^{(t+1)} = \max(x_i^{(t)} - \beta c_i^{(t)}, a_i)$ and $b_i^{(t+1)} = \min(x_i^{(t)} + \beta c_i^{(t)}, b_i)$, where β is a predefined contraction ratio. Set $t = t + 1$. Go to Step 1.

According to Fang and Wang's experience, they suggested $n_1 > n_2 = n_3 = \ldots$ for the processing. The contraction ratio β can be taken as 0.5. While Niederreiter and Peart (1986) suggested using $\beta_i = \beta^i$ as a contraction ratio at the i^{th} step with $\beta > 0$ as constant.

Remarks: in our case, at i^{th} step, $P_t(\boldsymbol{x}^{(i)}) \le P_t(\boldsymbol{x}^{(i-1)})$ in general for $i > 2$ only if $n_2 = n_3 = \ldots$. Or else, check the domain contraction process or stop the process of domain contraction, and take the $P_t(\boldsymbol{x}^{(i-1)})$ and the corresponding $\boldsymbol{x}^{(i-1)}$ as the optimal results.

3 APPLICATIONS

3.1 Discreterization Treatment of the Intersection Multi-objective Optimization for a Linear Programming Problem by Means of UTD

Take a multi-objective optimization of linear programming problem with three variables as our example.

The problem is written as following form,

$$\text{Max } f_1 = 9x_1 + 10x_2 + 14x_3,$$
$$\text{Min } f_2 = 4x_1 + 5x_2 + 8x_3. \quad (1)$$

The domain is [0, 12] × [0, 5] × [0, 7].

In this problem, f_1 belongs to beneficial type of performance, and f_2 is attributed to unbeneficial type of performance.

Table 1 Design and values of f_1 and f_2 of the multi – objective optimization of linear programming problem with three variables due to $U^*_{25}(25^{11})$

No.	x_1	x_2	x_3	f_1	f_2
1	1.20	0.90	6.86	115.84	64.18
2	2.64	1.90	6.58	134.88	72.70
3	4.08	2.90	6.30	153.92	81.22
4	5.52	3.90	6.02	172.96	89.74
5	6.96	4.90	5.74	192.00	98.26
6	8.40	0.70	5.46	159.04	80.78
7	9.84	1.70	5.18	178.08	89.30
8	11.28	2.70	4.90	197.12	97.82
9	0.24	3.70	4.62	103.84	56.42
10	1.68	4.70	4.34	122.88	64.94
11	3.12	0.50	4.06	89.92	47.46
12	4.56	1.50	3.78	108.96	55.98
13	6.00	2.50	3.50	128.00	64.5
14	7.44	3.50	3.22	147.04	73.02
15	8.88	4.50	2.94	166.08	81.54
16	10.32	0.30	2.66	133.12	64.06
17	11.76	1.30	2.38	152.16	72.58
18	0.72	2.30	2.10	58.88	31.18
19	2.16	3.30	1.82	77.92	39.70
20	3.60	4.30	1.54	96.96	48.22
21	5.04	0.10	1.26	64.00	30.74
22	6.48	1.10	0.98	83.04	39.26
23	7.92	2.10	0.70	102.08	47.78
24	9.36	3.10	0.42	121.12	56.30
25	**10.80**	**4.10**	**0.14**	**140.16**	**64.82**

The uniform table $U^*_{25}(25^{11})$ is employed to conduct the discretization of this multi-objective optimization of linear programming problem with three variables, the design together with the values of f_1 and f_2 are shown in Tab. 1 from Fang's book [12]. The assessment results of the partial favorable probabilities for f_1 and f_2 and the total favorable probabilities for each discrete point are presented in Tab. 2.

From the assessed results in Tab. 2, it can be seen that the maximum total favorable probability is at the point No. 25 with $x_1^* = 10.80$, $x_2^* = 4.10$ and $x_3^* = 0.14$.

Table 2 Assessment results of the partial favorable probabilities for f_1 and f_2 and the total favorable probabilities for each discrete point

No.	P_{f1}	P_{f2}	$P_t \times 10^3$
1	0.0362	0.0402	1.4543
2	0.0422	0.0355	1.4967
3	0.0481	0.0308	1.4834
4	0.0541	0.0262	1.4147
5	0.0600	0.0215	1.2904
6	0.0497	0.0311	1.5448
7	0.0557	0.0264	1.4700
8	0.0616	0.0217	1.3396
9	0.0325	0.0444	1.4416
10	0.0384	0.0398	1.5267
11	0.0281	0.0493	1.3863
12	0.0341	0.0447	1.5209
13	0.0400	0.0400	1.6000
14	0.0460	0.0353	1.6235
15	0.0519	0.0307	1.5915
16	0.0416	0.0402	1.6740
17	0.0476	0.0356	1.6915
18	0.0184	0.0583	1.0718
19	0.0244	0.0536	1.3048
20	0.0303	0.0489	1.4822
21	0.0200	0.0585	1.1699
22	0.0260	0.0538	1.3968
23	0.0319	0.0492	1.5682
24	0.0379	0.0445	1.6840
25	**0.0438**	**0.0398**	**1.7443**

3.2 Hybrid of the "Intersection" Multi-objective Optimization with SNTO in Treating the Linear Programming Problem

According to the procedure described in previous section, subsequent processing is used to contract domain to conduct further evaluations. Continue to deal with the problem of linear programming problem that was raised in the last section further for assessment that is more precious.

The uniform table $U_{19}^*(19^7)$ from Fang's book is used to perform the succeeding assessments [12]. Tab. 3 shows the consequences of the succeeding evaluations.

Tab. 3 displays that the $c^{(t)}$ value at the 5th step is 0.19%, if we set $\delta = 0.2\%$ as the pre-assigned small number for engineering application, then the final optimal consequences for this multi – objective optimization problem are $f_{1\text{Opt.}} = 135.2026$ and $f_{2\text{Opt.}} = 61.6421$ at $x_1^* = 11.9342$, $x_2^* = 2.7684$ and $x_3^* = 0.0079$.

Table 3 Consequences of the succeeding evaluations by using $U_{19}^*(19^7)$

Step	Domain	Optimum location			$f_{1\text{Opt.}}$	$f_{2\text{Opt.}}$	Max. total favorable probability $P_t \times 10^3$	$c^{(t)}$
		x_1^*	x_2^*	x_3^*				
0	[0, 12] × [0, 5] × [0, 7]	10.8000	4.1000	0.1400	140.1600	64.8200	1.7443	
1	[5, 12] × [1.8, 4.8] × [0, 4]	11.0790	2.8263	0.1053	129.4474	59.2850	2.8906	
2	[8, 12] × [2.5, 4] × [0, 2]	11.4737	3.0132	0.0526	134.1316	61.3816	2.8435	0.0163
3	[11, 12] × [2.6, 3.2] × [0, 1.0]	11.8684	2.8053	0.0263	135.2368	11.8684	2.8016	0.0147
4	[11.5, 12] × [2.7, 3] × [0, 0.5]	11.9342	2.8026	0.0132	135.6184	61.8553	2.7871	0.0052
5	[11.7, 12] × [2.7, 2.9] × [0, 0.3]	11.9342	2.7684	0.0079	135.2026	61.6421	2.7817	0.0019

4 CONCLUSION

From above discussion, it obtains following conclusions:

1) The hybrid of the uniform test design with the "intersection" method for multi – objective optimization is proposed, which simplify the complicated data processing of the evaluation. Therefore, the complicated data processing is successfully simplified as assessments of discrete points, which are evenly distributed within the test domain;
2) The "intersection" multi-objective optimization is combined with sequential uniform design, the detailed

procedure for searching optimum of the "intersection" multi-objective optimization with sequential uniform design algorithm is developed, which could be used to obtain a more precise approximation for solving multi – objective optimization problem;

3) The example for applying the novel approach to deal with the multi-objective optimization of linear programming problem with three variables indicates the validity of the current hybrids.

Conflict Statement

There is no conflict of interest.

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Authors' contacts:

Maosheng Zheng
(Corresponding author)
School of Chemical Engineering, Northwest University,
No. 229, Taibai North Road,
Xi'an, 710069, Shaanxi Province, China
E-mail: mszhengok@aliyun.com

Haipeng Teng
School of Chemical Engineering, Northwest University,
No. 229, Taibai North Road,
Xi'an, 710069, Shaanxi Province, China

Yi Wang
School of Chemical Engineering, Northwest University,
No. 229, Taibai North Road,
Xi'an, 710069, Shaanxi Province, China

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The Application of Virtual Tools in Teaching Dynamics in Engineering

Štefanija Klarić*, Alison Lockley, Katarina Pisačić

Abstract: Student success in Dynamics, a core subject in Mechanical Engineering courses, requires conceptual understanding of complex systems. Dynamics covers motion of particles and objects, and usually relies on 2 dimensional images and/or written descriptions to explain models and problems. This paper explores the value of visual representation of Dynamics problems with an assumption that it would facilitate student understanding of the content. Two approaches were applied for representation of Dynamics problems with the premise of Bring Your Own Device (BYOD): used with augmented reality and web animation activities. Responses from students and reflection from lecturers were collected and reviewed in relation to the applicability and the ease of use. Students and lecturers both appreciated the benefits of visual representation of complex models, and the possibility of manipulating with virtual objects. Lecturers also appreciated the easy access and use of tools during the class.

Keywords: augmented reality; engineering education; problem solving; virtual tools; visualisation

1 INTRODUCTION

Animated digital models enable the visual representation of systems easily accessible to different audiences, including learners new to a subject area. In engineering, complex problems with data and formulas can be visually presented in an animated 3D models, showing dimensions, forces, and movement. These types of animations are often used when engineers are sharing details about complex models with colleagues or clients, but are not commonly used with students. Likewise, augmented reality (AR) has been used in the engineering field, but not as commonly with students. AR overlays virtual objects, static or moving, on the real world and may utilise a range of advanced hardware and software systems [1] such as smartphones or specialised headsets. Use of digital representation like virtual reality (VR) and AR in engineering include engineering drawing and machine elements, electrical and civil examples [2-9]. AR has also been utilised in other fields including of higher education [10-15].

The need to better visualise technical models strongly relates to technical subjects such as engineering, particularly where real-life demonstration may not be possible: for example, a satellite in space. Driven by the commitment for improvement in student engagement and outcomes, in this paper different visualisation methods were trialled to ascertain their suitability and effectiveness.

Engineering Dynamics is a core subject in Mechanical Engineering undergraduate courses and often has students struggling to comprehend an array of complex systems that relate to motion of objects. With digital tools and online content offerings a standard in education today, the next step of inclusion of animated visualisations is a logical one. For example, with over 70% of students at Charles Darwin University (CDU) learning in a blended or fully online mode, it is important for suitable online tools to optimise student learning.

So far, most of the problems in Dynamics we represented through textbooks as 2 dimensional images. With this preliminary research, appropriateness of development and use of own digital representations of problems in Dynamics is explored as well as their use in classroom environment.

1.1 Visualisation Tools

With blended learning approaches leveraging online applications and innovative approaches, visualisation tools have gained increasing popularity to support student learning. Animated models have been shown to offer opportunity to challenge misconceptions [16] and see complex systems at work. It is also contemporary engineering work practice to utilise visualisations for project planning and presentations, and this practice should be modelled with students as part of authentic learning and assessment practices. In this era of digital information and Internet of Things prevalence, there is a growing significance of animation as a link between virtual and physical world [17].

AR has achieved a sufficient level of development for it to be considered as a relatively common application in many aspects of higher education as well as research [18-20]. However, the cost of development can be a significant challenge. Nevertheless, in recent years technology enhances and better accessibility has made it more achievable to create models and introduce them it into teaching environments. There are also requirements for enabling visualisations visibility on different devices with possibly minimising download or streaming requirements. Despite these challenges, there are undeniable benefits of implementing digital visualisation techniques [13, 21]. Being able to view a problem or model in motion, at different angles and take a closer look at specific components offers potential for better understanding and processing into cognitive schema, and improvement of the transfer of learning [22].

While developing effective visualisations for learning one should be aware of to the limitation of cognitive architecture, taking into consideration level of learner expertise. Moreover, visualisation needs to be constructed to maximise learning, and minimise confusion by incorporating principles of good multimedia design, using contemporary learning practice, approaches and research [23-25]. This

includes presenting information in a scaffolded way and allowing for accessibility. Further preferences on device/hardware use need to be accommodated: i.e., while some students prefer to use smaller handheld devices for learning, others prefer a desktop computer.

This paper explains visualisation tools used, and the specific educational approaches explored, at Charles Darwin University in Australia and University North in Croatia. Taking into consideration lecturer reflection and students' attitudes, this paper also discusses the benefits of visualisation tools and future opportunities.

Part of this research explored the value proposition for developing different types of visualisations. That is, we wanted to look at the time and cost involved, and weigh this against the benefit that would be received by a learner.

The visualisation tools included animated models accessed directly online and others via AR. The different approaches were trialled with students in 2 different locations: Australia and Croatia, and explored benefits including engagement, outcomes, and timeliness, as well as accessibility and re-usability of different objects. Each of the models gave a digital representation of the changes in time and space and allowed learner interactivity with the model being able to be viewed from different angles.

2 MODEL DEVELOPMENT

The selection and development of three models for trialling the usability of visualisation were based on the following requirements:

- Selected problems represent typical Dynamics examples (i.e., curvilinear motion of particles or rigid bodies),
- Problems (with copyright permission) are taken from Textbook used in class: J. L. Meriam, L. G. Kraige: Dynamics (Seventh edition) [26]

Two approaches were then selected for exploration with the models: application of an animated digital model that opened as a web page; and an AR model that required the use of mobile phone to open and manipulate with models. Both approaches were offered to students and presented in class (for face-to-face delivery) as well as made available (with accompanying explanations) on Learning Management Systems for external students.

2.1 Development of Digital Visualisations

Development of the visualisations used 3D modelling and open-source web and AR applications was based on the following assumptions and requirements accommodated in the development of the visualisations:

Assumptions:

- The platform for AR will have no cost to students.
- On campus students will have access to smart phones during classes to access the AR
- Online (and on campus) students will be able to access the same 3D models through a web browser.

Functional requirements:

- Where necessary the application will clearly demonstrate angles and motion in the exercises
- The application will engage students through attractive models and AR functionality
- Users will be able to scan a target or QR code using a free application.

Usability requirements:

- Users can scan a target and link with a 3D model
- Users can interact with the model, looking at different angles and rotating the model.

Accessibility requirements:

- Navigation:
  - No established patterns
  - Work for everyone; keyboard, mouse and touchscreens should all work.
- Clarity:
  - Too much motion may be confusing
  - Complex background may distract from the model
  - Insufficient contrast may make it difficult to some users to identify key features
- Users can manipulate and navigate models using keyboard, mouse or touch screen controls.
- The exception to this is AR where models must be navigated using location and orientation controls to maintain the AR illusion
- Users should be able to pause animation or motion to avoid confusion
- Models should have a strong contrast with their background. Text should target an AA rating according to WCAG 2.0 guidelines 1.4.3 where possible.
- Attached text should explain key details of the models

The development process used an agile approach, with iterations tested with users and feedback used to direct improvements in design and functionality.

2.2 Animated Digital Models Accessed Directly Online

Three problem examples were prepared as online animated models.

Example 1: Model of an airplane flying on a circular path. This first example is related to curvilinear motion of particles [26]. The aim of this exercise is to present Free Body Diagram and the use of normal and tangential coordinate system to calculate the force value. Students were asked to calculate the force exerted on the pilot at particular points. This example contained animation without accompanying problem text (Fig.1).

Example 2: Model of spacecraft (satellite) rotating about its z-axis. This example is related to rotation of rigid body [26]. Students were supposed to determine the angular velocity of the body after the panels are rotated to a particular position. The aim of animation is to show students how the change of geometry (in this case rotation of the solar panels) can influence mass moment of inertia (and rotational speed).

In this example problem text was placed on a page with the model (Fig. 2).

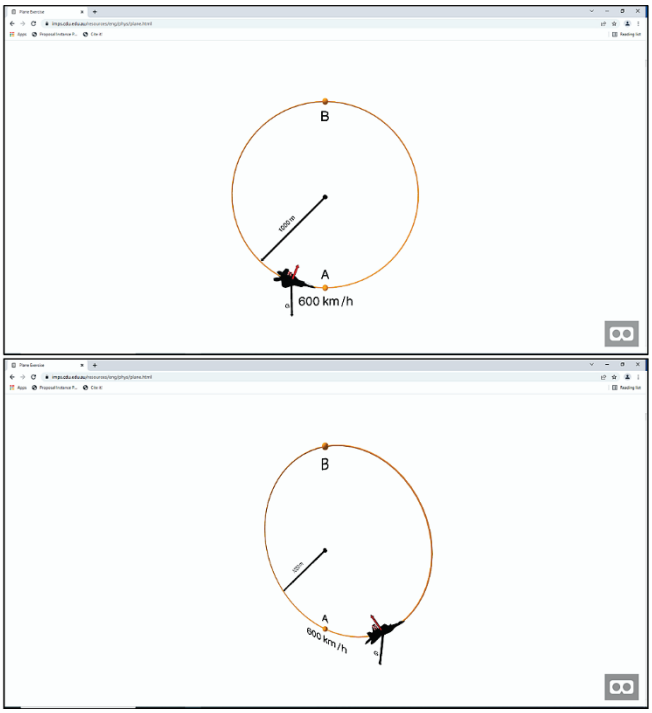


Figure 1 Curvilinear motion of the airplane and forces acting presented in online animation

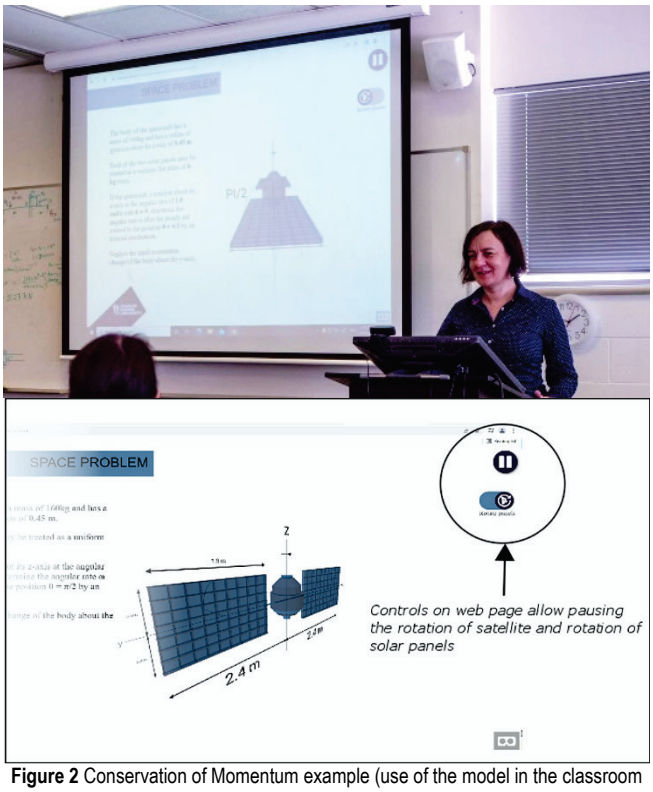


Figure 2 Conservation of Momentum example (use of the model in the classroom and controls on web model)

Example 3: Model of diver leaving a diving platform. This was another example related to dynamics of rigid body (impulse - momentum equations) [26]. The aim was to show students how the change of geometry influences the change of mass moment of inertia and how geometry of the complex bodies can be represented with more simple geometrical shapes (cylinder and sphere – Fig. 3). Students then estimate the angular velocity when the diver has assumed the tuck position (sphere shape).

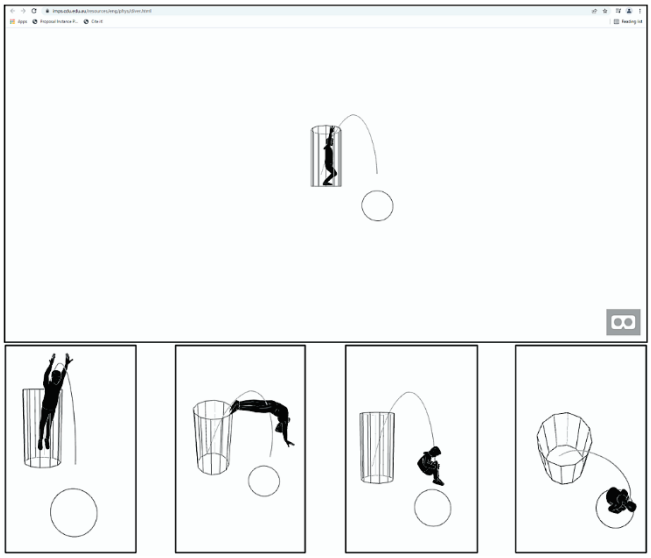


Figure 3 Second conservation of Momentum example

2.3 Augmented Reality

Examples 1 and 3 were also prepared as AR models that students could access from their mobile phones (Figs. 4 and 5) via QR code links. Printouts of the QR code were given to students during the class and published online for external students.

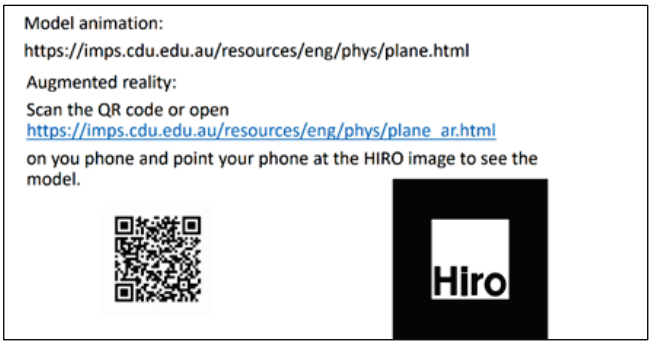


Figure 4 QR code and links for web and AR plane model

3 EXPERIENCE REVIEW

3.1 Students' Attitude towards Used Models

Two groups of participants (with classes run by two lecturers) took part in the trial of animated digital models via webpage and AR; students studying engineering at Charles Darwin University, Australia and students studying engineering at University North, Varaždin, Croatia.

Students completed activities that used the models as part of classroom work with lecturers present. Also, students were free to choose and interact with the animated digital

models at their own pace, to solve specific questions. Students were encouraged to view the models from different angles and manipulate them.

After the subject delivery, a short survey was conducted (at this stage only with internal students) to find out student's attitude towards the use of visualisation tools as well as to gauge their preferences regarding the use of web pages/AR models, as well as if there are any suggestions for improvements or innovative ideas.

While both student groups interacted with the models in class, the analysis of the survey was only based on 19 responses from students of University North, Croatia. This was due to the very small number of responses from Charles Darwin University students.

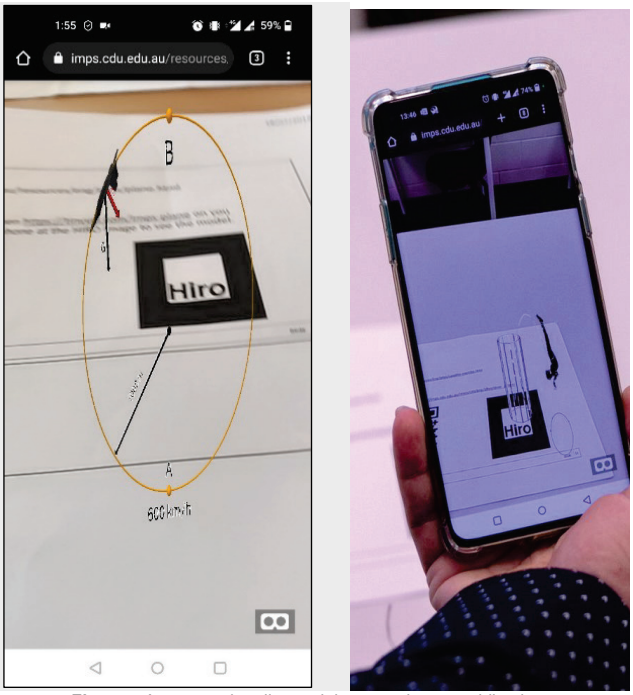
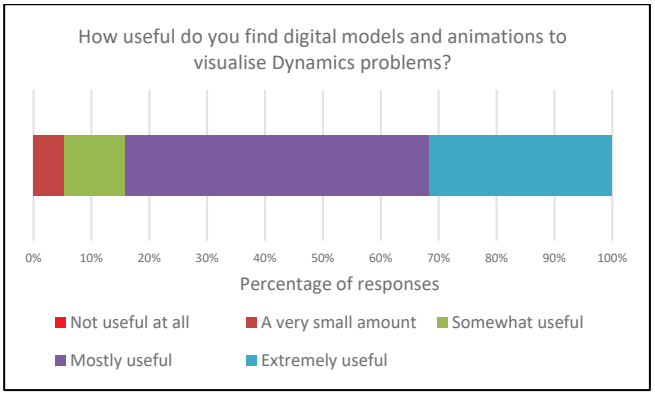


Figure 5 Augmented reality models opened on a mobile phone

The survey consisted of 6 questions:

1. How useful do you find digital models and animations to visualise Dynamics problems?
2. Did the use of digital models and animations help you to better understand the mechanics principles and solve problems?
3. To what extent you agree with this statement: "The implementation of augmented reality could help me feel more engaged in my study"?
4. If you had to choose between viewing an animated digital model either on a web page or via an augmented reality layered image, which would you choose?
5. Does the use of digital models and augmented reality encourage critical thinking and devising what-if scenarios?
6. Please give your thoughts and suggestions about use of digital models and augmented reality in Engineering.



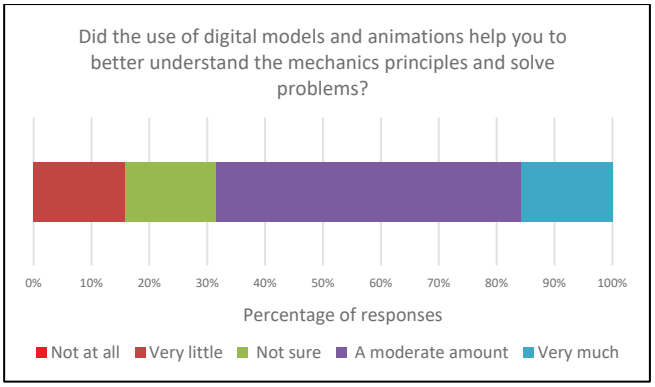
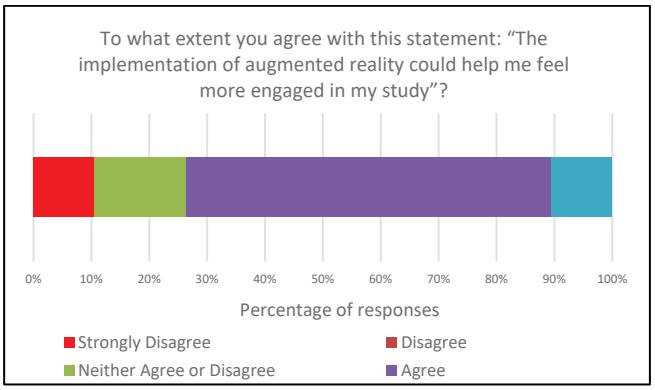


Figure 6 Students' responses related to usefulness of digital models (Survey questions 1 and 2)



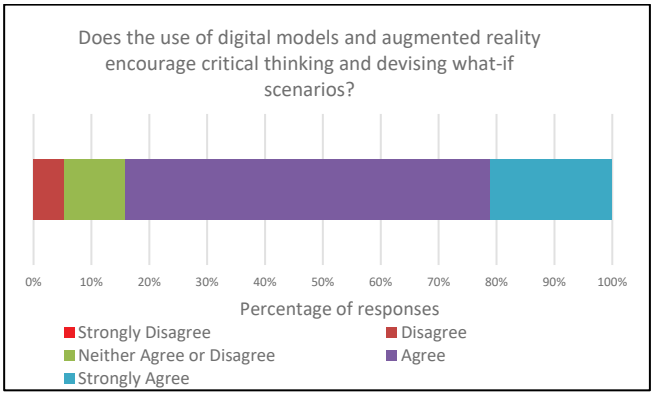


Figure 7 Students' agreement related to engagement and critical thinking (Survey questions 3 and 5)

Student's attitude to the visualisation models from the survey questions is presented in Figs. 6-8. Based on the analysis it is evident that student's attitude toward these innovative approaches and refreshment in content delivery is positive, and majority of students agree that these approaches could encourage critical thinking and engagement, as well as improve understanding of complex problems. Also, in their answers, students tend to appreciate AR examples more than web-based representation of the problems. However, it is important to take into consideration low survey sample size.

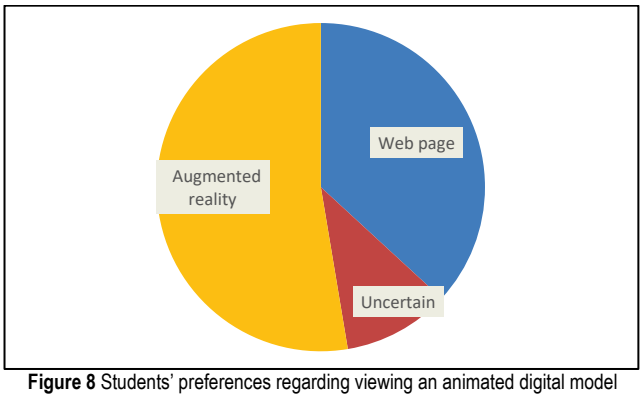


Figure 8 Students' preferences regarding viewing an animated digital model (Survey question 4)

3.2 Lecturers' View and Discussion

From the lecturers' perspective these tools did allow better presentation of dynamics problems, allowing observing forces or movement of segments in 3D space. For teaching face to face (in classrooms) web pages proved to be more efficient as opening and manipulating with 3D object was possible in a quick way with added text and all details that were easy to present (Fig. 2).

Introducing AR models during class time did provide full engagement of students, however setting up devices and opening models on their mobile phones took some of their time and attention away from the actual Dynamics problems. This time impost would be reduced with future use, as students gain familiarity with the use of the tools and how to access the models.

Further there was a significant development time for each of the examples. While there is a value in reuse of visualisations, the initial build of a small suite of visualisation models required significant time (and development cost). Investment in improvements that lead to greater engagement and learning success are worth pursuing, but the number of examples developed would need to be rationalised against budget, timeframes and priorities of other learning approach improvements. However, with continuing advancement with technology there could be modelling applications that make development much quicker and easier.

4 CONCLUSION

The aim of this case study was to develop digital representation of a few typical examples of Dynamics problems and observe their appropriateness in teaching and learning. The trial with 3 different Dynamics models included evaluating efficiency of their development, their effectives in classroom as well as lecturer and students' attitudes toward them. While 2 different groups of students were involved in the study, only the results from one of the groups was of sufficient number to include in the analysis.

The scope of this study was primarily with students studying in internal mode (models were used in classroom). For the future research it would be useful to review students' preferences (web or AR) for purely online deliveries and/or for individual study.

This study shows the positive impact of digital visualisations and virtual tools on student engagement and learning. While only a relatively small study it adds to a larger body of work being done with online tools and AR. The potential and options for AR and visualisations in education are rapidly involving and look play an important role in future approaches. The use of AR and web models for visualisations also prepares students for work beyond their studies by using relevant contemporary technologies utilised in industry.

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Authors' contacts:

Štefanija Klarić, Associate Professor Dr.
(Corresponding author)
College of Engineering, IT and Environment, Charles Darwin University,
Ellengowan Drive, Casuarina, NT 0810, Australia
+61889466416, stefanija.klaric@cdu.edu.au

Alison Lockley
Digital Learning Design, Charles Darwin University,
Ellengowan Drive, Casuarina, NT 0810, Australia
+61889466318, alison.lockley@cdu.edu.au

Katarina Pisačić, Mag. ing. mech.
Mechanical Engineering Department, University North,
Jurja Križanića 31b, 42000 Varaždin, Croatia
+385998003733, katarina.pisacic@unin.hr

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A Black-Box Computational Business Rules Extraction Approach through Test-Driven Development

Emad Albassam

Abstract: Business rules extraction is an important activity in situations in which a software system becomes obsolete and needs to be replaced by a newer system, since the replacing system needs to satisfy the business rules embedded in the legacy software system. In this paper, we investigate an approach in which the computational business rules of a legacy software system can be extracted given previously generated output of the system and without requiring access to the system's source code. Furthermore, extracted computational business rules are validated automatically with minimal involvement of domain experts through Test-Driven Development (TDD) such that test cases are constructed from historic output of the system. The proposed approach is applied to extract the computational business rules of a large-scale governmental payroll legacy software system. The study results demonstrate that the suggested approach extracted computational business rules van meet a substantial number of test cases. Thus, the efforts involving domain experts can be reduces to analyze such instances.

Keywords: business rules extraction; legacy software systems; software modernization; test cases

1 INTRODUCTION

Software Evolution is regarded as a term that refers to the procedure of developing software initially, then timely updating it for different reasons, for instance, to add new characteristics or to terminate obsolete functionalities, etc. [1-3]. Some legacy software systems cannot be feasibly modified or expanded further [2, 4, 5]. Thus, many organizations evolve their legacy software systems through redevelopment or replacement of these systems to sufficient support business goals. Such goals may include (1) switching from a legacy programming language to a modern language, (2) adopting a flexible software architecture for the software system (such as switching from a monolithic architecture to a microservice architecture), and (3) targeting a new operational environment (such as switching from Mainframe environment to Cloud environment) [6-8]. To accomplish such evolution activities, the replacing software system is often needed to fully or partially satisfy the business rules embedded in the legacy software system. Nevertheless, since multiple legacy software systems are either partially documented or lack any documentation of their development [9-12], the business rules embedded in these systems must be extracted first to accomplish software evolution.

Although there exist approaches in the literature for business rules extraction from legacy software systems, such approaches require (1) access to the source code of the legacy software system for analysis and (2) involvement of domain experts to manually validate the extracted business rules. In this paper, we discuss an approach in extracting computational business rules. The proposed approach does not require access to the source code of the legacy software system. Instead, we rely on collecting and analyzing historic output of the legacy software system to extract such computational rules [13-16]. Furthermore, the extracted computational business rules are validated automatically against test cases that are constructed from historic system output using TDD. The application of the proposed approach is illustrated in which the computational business rules are extracted from a large-scale governmental legacy software system.

The remainder of the paper is organized as follows: section 2 discusses works related to business rules extraction from legacy software systems. Section 3 provides the background of our work. Section 4 describes our approach for business rules extraction. Section 6 contains the discussion and threats to validity. Section 7 contains the conclusion.

2 LITERATURE REVIEW

Although business rules extraction is considered an important activity in legacy software system evolution and replacement, a systematic review by Normantas and Vasilecase [17] concluded that there is a lack in the number of publications in this area suggesting that this field requires more research efforts.

To better position our work with existing research efforts, we classify business rules extraction approaches based on whether they require (1) access to the source code of the legacy software system (i.e. white-box approaches) or not (i.e. black-box approaches) and (2) involvement of domain experts to validate extracted business rules, as discussed next.

2.1 White-Box Business Rule Extraction Approaches

The majority of existing approaches in the literature are considered white-box such that the source code of the legacy software system is assumed to be known in order to accomplish the extraction activity.

Work by Wang et al. proposed a tailored approach for business rules extraction from legacy software systems [4]. Their approach relies on (1) slicing the legacy system's code into smaller related units, (2) identifying domain variables in each slice, (3) analyzing domain variables and integrating

them into business rules with the help of domain experts, and (4) validating extracted business rules. Earls et al. [5] described a method in which the source code of legacy software systems is analyzed to determine the conditions at which error processing sections are invoked. Such conditions are then captured, translated, and recorded as business rules which are then evaluated by domain experts. In their works, Hatano et al. [8] discussed an approach for understanding business rules in software systems in which the source code of the system is analyzed to determine conditional statements that affect the computation of variables used to generate system outputs.

Work by Cosentino et al. [6] discussed a model-driven reverse engineering framework for extracting the business rules in COBOL legacy software systems in which the source code is analyzed and sliced to extract business-relevant statements. Pichler showed how business rules can be automatically extracted from legacy software code through symbolic execution [18,19]

Compared to these approaches, our approach extracts computational business rules of a legacy software system without requiring access to the system's source code (i.e. a black-box approach). Furthermore, we show how the extracted business rules are automatically validated with minimal involvement of domain experts.

2.2 Black-Box Business Rule Extraction Approaches

There have been some research efforts that consider the extraction of business rules from artifacts other than the source code. Chaparro et al. [10] investigated how structural business rules can be recovered from a legacy system's database. Paradauskas and Laurikaitis [9] also proposed an approach in which business knowledge is extracted from the relational database of legacy software systems combined with analysis of their source code. In their approach, a data reverse engineering algorithm is responsible for schema extraction and semantic analysis. Their approach is augmented with source code analysis to identify new business rules that are not explicitly stored in the database. Compared to such approaches, we consider the extraction of computational business rules from previously generated output of the legacy software system.

A research by Jin et al. [18] described an approach in which the business rules of a software system is extracted from historic test cases which had been previously constructed for the system as the software system evolves. Work by Martínez-Fernández et al. [7] proposed an automated process for extracting business rules in the banking industry from unrestricted text via SBVR (Semantic Business Vocabulary and Rules) standard and OWL language, which is considered a domain-specific approach. However, such approaches are considered domain specific.

2.3 Test-Driven Development: Background

In Test-Driven Development (TDD) [20-23], the specifications of a new software system are first captured in test cases followed by incremental implementation of the software system. As the software system is being implemented, test cases are executed to evaluate the correctness of the currently implemented parts of the software system, where the goal is to satisfy the constructed test cases at the end of the implementation process. Therefore, test cases in TDD are used to ensure that the software implementation adheres to the intended software specifications.

In our approach, we incorporate the concept of TDD to ensure that extracted computational business rules of the legacy software system satisfy the observed output that was previously generated by the legacy software system. Specifically, we generate test cases such that the expected results of test cases are derived from historic system output. When computational business rules are extracted, these rules are executed to produce actual results which are then evaluated against the test cases, therefore minimizing the role of domain experts involved in evaluating the extracted business rules.

2.4 A Black-Box Approach for Extracting Computational Business Rules

Our black-box approach to extract the computational business rules consists of 5 phases (see figure 1). As can be seen from the figure, the approach involves (1) analyzing whether black-box extraction of computational business rules is suitable for the project, (2) gathering initial information to facilitate the extraction process (such as historic system output), (3) constructing test cases from gathered information, (4) extracting computational business rules, and (4) evaluating the extracted rules using constructed test cases.

The remainder of this section describes the details of each phase. To illustrate each phase, we applied our approach to extract the computational business rules of a real-world legacy software system used in a large-scale governmental agency. The scope of the project as per stakeholder request is the *payroll* component of their legacy software system which is an information system responsible for generating the payrolls of the agency's employees. The payroll component is developed in-house by the agency through its IT department using the COBOL programming language and incorporates CICS transactional processing and runs on an on-premises Mainframe environment. The agency's business goal for the modernization project is twofold. First, the agency aims to lower its operational costs by switching from the Mainframe environment to operating its services on the cloud. Second, the modernization project aims to ensure continuous maintenance sustainability by rebuilding this component using a modern programming language due to the lack of national practitioners with appropriate qualifications in COBOL programming and CICS technology. We consider the payroll component as large-scale since it is responsible for generating the monthly payrolls of more than 15,000 employees in this agency. Furthermore, the agency is part of the country's higher-education sector and hires employees from different cadres such as the academic cadre, administrative cadre, and health cadre. Therefore, the

computational business rules that are responsible for computing the employee payrolls differ based on their cadres.

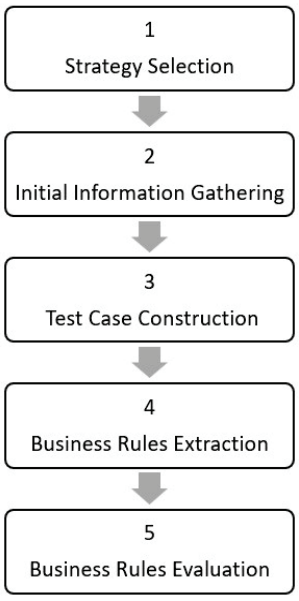

Figure 1 Phases involved in extracting computational business rules

2.5 Strategy Selection

In order to select an appropriate strategy for business rules extraction for this legacy software system, we analyzed and identified risks and challenges of this project. This identification process is accomplished by means of interviews with key stakeholders which revealed the following:

- *Lack of documentation*: as with many legacy software systems, interviews with the agency's IT personnel revealed that the payroll system lacks any documentation of its analysis, design, and implementation. Therefore, the computational business rules must be first extracted from the legacy software system in order to proceed with software replacement.
- *Improper implementation practices*: inspection of the legacy payroll system's artifacts revealed that the source code suffers from many improper implementation practices, such as overuse of GOTO statements (i.e. "spaghetti code"), unnormalized database design and lack of relations, and ambiguous naming convention. Therefore, techniques that rely on reverse engineering of source code may result in incomplete models that require substantial manual efforts to analyze, revise, and validate.
- *Retirement of original programmers*: interviews with the current programmers of the agency revealed that the original programmers of this component have either retired or left the agency. Furthermore, no current programmers have the full knowledge of the complete implementation of the payroll component such that implementing new change requests may require them to manually inspect and analyze unknown parts of the code. Therefore, relying on interviewing the current software system's programmers to obtain the computational business rules may result in requiring the programmers to inspect and analyze the entire source code, which is an error-prone process and may increase the costs and time for the project.
- *Negative previous experiences*: through project interviews, it has been discovered that the organization has gone through a previous, failed attempt to modernize its legacy systems. As a result, key stakeholders, such as HR and finance department personals, have conveyed frustration with such projects during interviews, which may negatively impact their effective participation.

Due to these factors, we consider an approach in which the computational business rules need to be (1) extracted without accessing the source code and (2) validated with minimal domain expert involvement.

2.6 Initial Information Gathering

Next, we gathered preliminary information related to the payroll legacy system that is either readily available or directly observable from the legacy software system, as follows:

- *Historic system output*: we collected observable, previously generated output from the payroll legacy software system representing the monthly employee payrolls. We observe that although the software is complex in terms of its implementation, its output is structural and well-defined. This historic system output is then analyzed to construct (1) an entity-relationship diagram (ERD) of the system output (as shown in figure 2), and (2) a data dictionary table for this ERD. Therefore, the goal of the extraction process is to extract the computational business rules responsible for generating the computed values of the output (e.g., BASIC SALARY and ELEM AMT of employee payrolls in figure 2).
- *Instances and their features*: we analyzed the database of this legacy software system (including tables, relationships, columns, and records) to identify attributes that could be used by computational business rules to compute the system's output. Specifically, we analyze the database to define the set of instances I (such that each instance $i \in I$ represents an employee of the organization) as well as the set of features for each instance f_i such as the status, gender, department, rank, and grade of employees.
- *Initial computational business rules*: we gathered the salary ladders for the various cadres in this agency. Each salary ladder is associated with a particular cadre (e.g. academic cadre, administrative cadre, and health cadre) and defines the monthly *base salary* for an employee given the employee's current rank and grade. Salary ladders are unified across this country's governmental agencies and are publicly available. Fig. 1 shows an example of a salary ladder for the Academic cadre. In the proposed approach, this information serves as the *initial computational business rules* from which additional computational business rules will be extracted.

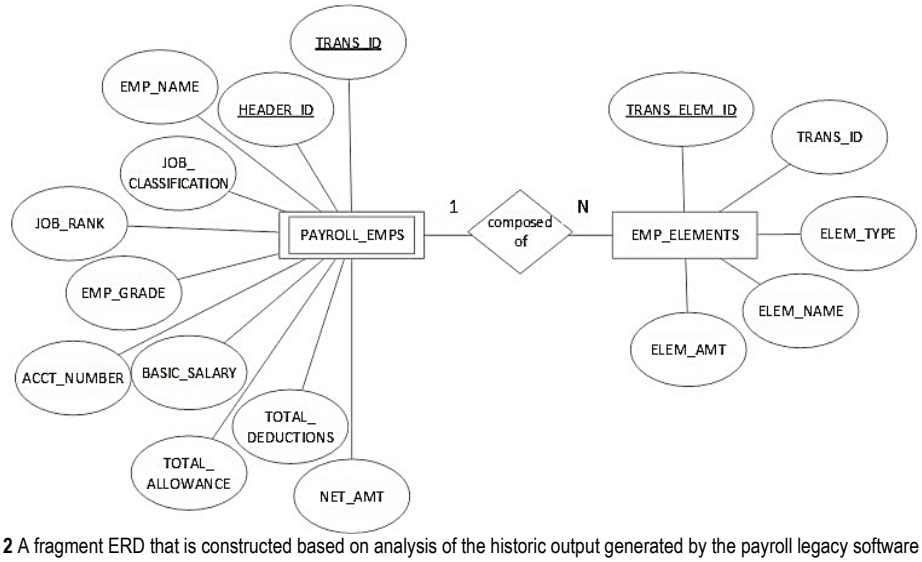

Figure 2 A fragment ERD that is constructed based on analysis of the historic output generated by the payroll legacy software system.

2.7 Test Cases Construction

Given the risks and challenges, our approach relies on automatically validating extracted business rules with minimal involvement of stakeholders and domain experts. To accomplish this, we adopted the Test-Driven Development (TDD) in which test cases are developed from the historic outputs of the legacy software system. The premise is that since the output of the legacy software system represents the results of applying the computational business rules embedded in the system, then we can use previously generated outputs of the legacy software system to automatically validate the correctness of extracted business rules. Therefore, we constructed test cases such that the *expected results* of test cases are mapped to the computed values obtained from historic system's output (e.g., BASIC _SALARY and ELEM AMT in Fig. 2). For example, if the historic output shows that an instance received the amount 6,650 as BASIC_SALARY in a particular month, then a test case is constructed for that instance and month with this amount as the expected result.

2.8 Business Rules Extraction

In this phase, we extract computational business rules by analyzing correlations between the expected results obtained from the historic system output and the actual results computed from initial business rules according to the following steps:

2.8.1 Computing the Actual Result for Each Instance

In this step and given the set of initial business rules and the set of instances $I = i_1, ..., i_n$ obtained previously during phase 2, we computed the *actual results* $A = a_{i1}, \ldots, a_{in}$ for the instances by applying the initial business rules B on each instance as follows:

$\forall i \in I$, $a_i = C(B, f_i)$, where f_i is the features defined for instance i.

As an example of this step, for an Academic employee with the rank *Teaching Assistant* and Grade 1, the actual result for his basic salary is 6,650 based on the initial business rules (see the academic salary ladder shown Tab. 1).

Table 1 Example of the obtained salary ladders. This example shows the Academic salary ladder in which the base salary of an academic employee is determined given his/her current rank and grade.

Rank	Grade					Annual Allowance
	1	2	..	14	15	
Teaching Assistant	6,650	7,065	..	12,045	12,460	415
Lecturer	8,765	9,275	..	15,395	15,905	510
Assistant Professor	12,765	13,335	..	20,175	20,745	570
Associate Professor	16,080	16,745	..	24,725	25,390	665
Professor	18,420	19,155	..	27,975	28,710	735

Note: the salary ladder has been shortened for space consideration.

2.8.2 Computing the Difference Percentage between the Actual Result and Expected Result for Each Instance

For each instance, we compute in this step the difference, in percentage, between the actual result for the instance (as computed in the previous step) and the expected result for this instance (as obtained from the historic output of the system).

Specifically, given the expected results $E = e_{i1}, ..., e_{in}$ which is obtained from historic system output for the set of instances I and (2) the computed actual results, $A = a_{i1}, \ldots, a_{in}$, we computed the difference percentage for the instances as follows:

$$\forall i \in I, d_i = \left| \frac{e_i - a_i}{e_i} \right| \times 100. \quad (1)$$

As an example of this step, if the expected result for the basic salary of an Academic employee (as per historic system output) is 7,065 and the obtained actual result for this employee from the previous step is 3,532.5, then the difference percentage is 50%.

2.9 Correlating Data

We calculate the correlations between the difference percentages computed previously and the instance features, where the goal is to find the association strength between them. To accomplish this, we use the following:

a) Pearson's *R* for correlating continuous data.
b) Correlation Ratio for correlating categorical data with continuous data.
c) Cramer's V for correlating categorical data.

The result is a heat map (see Fig. 3) that depicts the correlation between instance features such that as the correlation value between two features increases, the strength association between the two features becomes stronger indicating a significant and positive relationship. On the other hand, the value 0 indicates no correlation between features.

For example, Fig. 3 shows that there is a significant relationship between the difference percentage and the status of an employee for computing basic salaries of Academic employees, while the correlation between the difference percentage and marital status is insignificant. Strong correlations are analyzed further to extract computational business rules as explained in the next step.

2.10 Analysis of Correlated Data

At this step, strongly correlated features are analyzed to detect patterns of changes between actual results and expected results in instances using *histograms*. The majority of instances have 0% changes (i.e. earned basic salary is equal to the amount indicated by the salary ladder) while approximately 28% of instances have 50% of changes between their actual and expected results (i.e. academic employees earned a monthly basic salary equal to half the amount indicated by the salary ladder). In addition, some instances have 100% difference between their actual and expected results (i.e. no basic salary is earned by these instances).

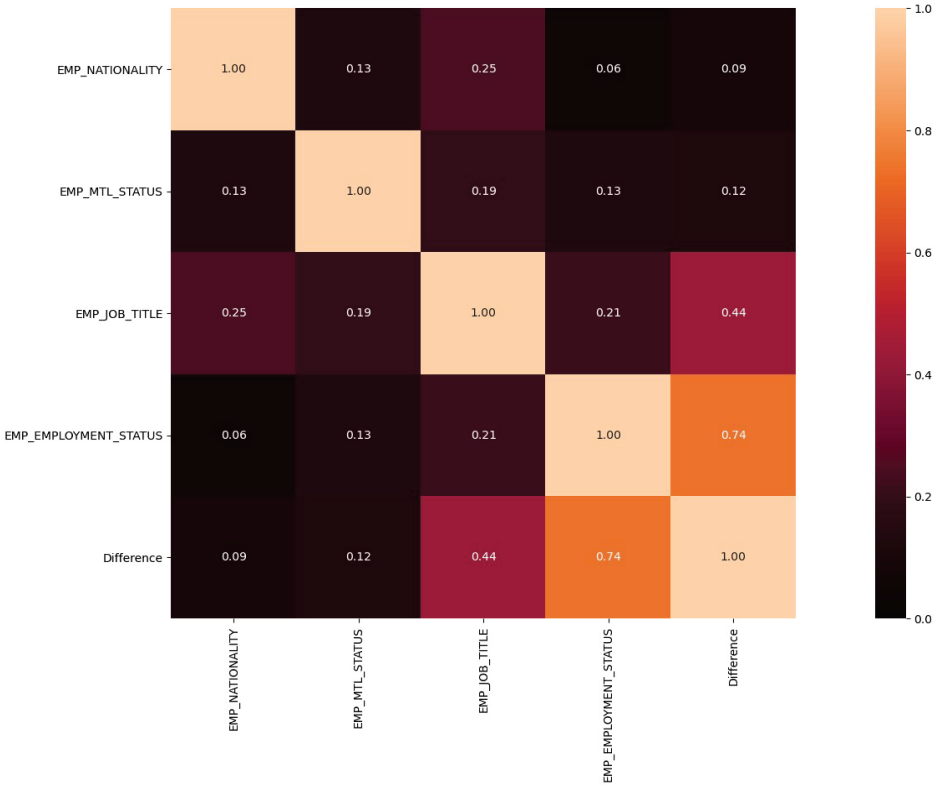

Figure 3 A fragment of the Academic cadre heat map for the Basic Salary

Such patterns are then converted into new computational business rules based on correlation results obtained from the previous step. For instance, the heat map shown in Fig. 3 indicates that the status feature of an academic employee affects his/her basic salary. By analyzing the status feature of each category we define the following computational business rules:

a) If the *status* of an academic employee is *scholar*, then the employee earns 50% of the base salary indicated by the academic salary ladder.
b) If the *status* of an academic employee is *suspended*, then the employee earns 0% as base salary.
c) If the *status* of an academic employee is *Member of the country's Consultative Council*, then the employee earns 0% as base salary.

d) Similarly, other business rules were analyzed and extracted. The following are examples of extracted business rules related to various instance features:
e) If an academic employee is assigned as a department chair, a 1500 allowance is given.
f) If an academic employee is assigned as a vice dean, a 2000 allowance is given.
g) If an academic employee is assigned as a dean, a 2500 allowance is given.
h) A monthly retirement agency deduction is applied equal to %0.09 of the academic employee basic salary.
i) If an academic employee is teaching the full load of credit hours, then the employee earns an allowance equals to the amount of the first grade in his/her current rank from salary ladder.

2.11 Evaluation of Business Rules

Initial and extracted computational business rules are evaluated at this step using the test cases constructed previously in phase 3 for every defined instance. That is, for every instance (i.e., employee), we execute the computational business rules (both initial and extracted) to compute the actual results for that instance (e.g., basic salary, allowances, and deductions) and then compare the actual results with the expected results obtained from historic system output. This evaluation relies on three metrics as follows:

a) Total number of constructed test cases.
b) Number of passed test cases: this metric indicates the number of test cases that passed such that the expected result match the actual result.
c) Number of failed test cases: this metric indicates the number of test cases that failed such that the expected result did not match the actual result.

To track these metrics more easily, we have categorized the test cases based on cadre type (e.g. academic, administrative, etc.) and payroll element type (e.g. base salary, allowances, deductions). Fig. 4 shows a fragment of the evaluation results obtained for the Academic cadre. For example in the department chairman allowance, 223 test cases were constructed of which 217 has passed and only 6 has failed. This indicates that the extracted business rule for computing this allowance has covered 97% of instances in the historic system output.

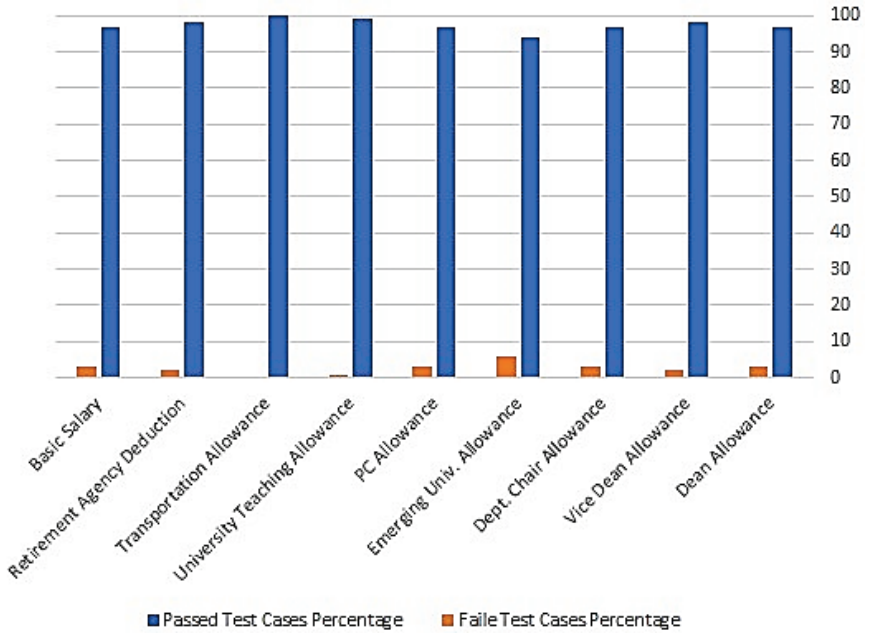

Figure 4 Fragment of evaluation results showing percentages of passed and failed test cases for the Academic cadre for various payroll components

3 RESULTS AND DISCUSSION

In spite of the fact that the extracted computational business rules through the proposed approach have covered a high percentage of the instances obtained from the output of the legacy payroll system, the proposed approach did not cover all business rules due to the existence of failed test cases. Therefore, such failed cases require further analysis by domain experts and stakeholders. Having said that, the approach is able to pinpoint these cases for further analysis. Plus, since the number of failed test cases is limited, then the effort of manual analysis is limited to the instances corresponding to these cases.

It is worth mentioning that the approach did not cover business rules associated with some cases because of factors such as (1) some instance did not follow any business rules embedded in the legacy software system (e.g. some allowances are specified manually by an HR personal such that no business rules for these components are implemented in the legacy software system) and (2) some instances follow very complex business rules in which multiple features may impact the computations.

This studied approach assumes that initial business rules must be gathered in order to extract additional rules. Moreover, the approach relies on the availability of historic system outputs. In addition, the approach requires the historic state of instance features to reproduce generation of historic system outputs. For example, historic information related to the Rank, Grade, and status of an academic employee is required to reproduce the historic basic salary of this instance.

However, it can be concluded that the approach can assist in extracting substantial computational business rules. The results of this study can contribute to decreasing the efforts involving the stakeholders and domain experts by focusing on discovering instances for which no business rules were extracted. In addition, the approach enables automatic evaluation of extracted business rules via test cases with the aid of a Test-Driven approach.

4 CONCLUSION

The present investigation endeavored to discuss a method for extracting the computational business rules of a large-scale governmental payroll legacy software system utilizing Test-Driven Development (TDD). We examine in this approach a black-box computational business rules extraction process in which no knowledge of the system's source code is assumed to be comprehended. To achieve this, we rely on computing correlations derived from the historical output of the legacy software system. Such correlations are then analyzed to extract computational business rules.

Moreover, we regard the evaluation of extracted business rules using Test-Driven development. Evaluation results show that the proposed approach extracted computational business rules that satisfied many test cases. Furthermore, the process helps pinpoint instances where no computational business rules are extracted. Thus, domain experts' efforts can be minimized to analyze such issues.

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Author's contacts:

Emad Albassam, Assistant Professor
Department of Computer Science,
Building FCIT Building, Room 148,
King Abdulaziz University, Jeddah, Saudi Arabia
ealbassam@kau.edu.sa

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Possibilities of Evaluating the Dimensional Acceptability of Workpieces Using Computer Vision

Ilija Svalina*, Dražen Turinski, Ivan Grgić, Sara Havrlišan

Abstract: This paper discusses the possibilities of an automated solution for determining dimensionally accurate and defective products using a computer vision system. In a real industrial environment, research was conducted on a prototype of a quality control machine, i.e. a machine that, based on product images, evaluates whether the product is accurate or defective using computer vision. Various geometric features are extracted from the obtained images of products, on the basis of which a fuzzy inference system based on Fuzzy C-means clustering features is created. The extracted geometric features represent the input variables, and the output variable has two values - true and false. The root mean square error in the evaluation of the accuracy and defectiveness of products ranges between 0.07 and 0.16. Through this research, valuable findings and conclusions were reached for the future research, since this topic is poorly examined in the most renowned databases.

Keywords: computer vision; dimensional control; fuzzy C-means clustering; image processing; vision measurement

1 INTRODUCTION

Possibilities and advantages of implementing a computer vision system or a somewhat less extensive machine vision system, which is a subset of computer vision, represent a long-recognized interdisciplinary technology. The main conditions for the application of technology based on computer vision were related to the level of development of software and hardware products and the speed of processing large data sets. Creating digital systems consisting of one or more cameras and computers for the purpose of processing, analyzing and understanding digital images and extracting meaningful and purposeful insights from the digital input (digital image) is the main objective of computer vision. Computer vision, as a field of artificial intelligence, mostly includes research of replication and imitation of human vision segments, which are later used through the machine vision system to determine various actions such as automated tasks in the industrial or manufacturing environment. Technologies and methods cover a wide range of application areas: automated control (inspection), process control, face recognition, object recognition or detection, image search, object tracking, etc. Since 2010, the development of computers and the availability of large databases has enabled a more significant application of deep learning methods in the sense of applying computer vision, from autonomous driving and robotics to various applications in detecting and recognizing certain areas or zones of interest in digital images [1].

The review of scientific literature below will present the scope and diversity of the application of methods and technologies based on computer vision. In paper [2], the developed machine vision system is used for inspection and evaluation of fruits in terms of detecting external faults since the consumers associate fruit quality with good appearance and the total absence of external faults, which ultimately significantly affects the market price. An important feature of methods and technologies based on computer vision is their non-destructive nature (non-destructive procedures). Security surveillance in terms of access control and human recognition is the main focus of research conducted in paper [3], where the authors developed a precise method for detecting human faces using a hybrid neural network. Paper [4] presents a computer vision system that conducts plant phenotyping based on features such as plant volume, leaf surface area and stem length. The proposed computer vision system combines the best of the 2D imaging approach with the three-dimensional (3D) reconstruction method. Similar to the aforementioned paper, important information for agriculture is the measurement of surface area and volume in food processing, for which a machine vision system has been developed in paper [5]. The three-dimensional wire-frame model of the object is reconstructed by integrating silhouettes recorded from different viewing angles. In paper [6], dimensional analysis of geometric figures is performed using computer vision, while paper [7] analyzes the use of smartphones as machine vision devices, with the focus on drilling. Using the machine vision method, the measurement of required parameters according to the ISO 10545-2 standard, which refers to the dimensional deviation of ceramic tiles, is performed in paper [8]. The final paper in the first part of the scientific literature review is paper [9], which investigates specular surfaces as one of the significant limitations of computer vision. Specularity of outer surfaces directly caused by ambient lighting makes it difficult to accurately reconstruct the product, especially when detecting faults such as bumps, cracks and scratches present on the product.

Unlike the first part of the scientific literature review, which intends to present a part of the scope and diversity of application, the second part of the scientific literature review refers to the creation of 3D models from a set of images, i.e. 3D reconstruction. This part also includes the previously mentioned papers [4, 5] and [9]. In paper [10], machine vision technology is used to evaluate the logarithmic spiral bevel gears. Two cameras at different locations capture images of the gear using correspondence between the feature points of these two images to solve the three-dimensional

coordinates of the tooth surface points. Manner of estimating 3D measurement errors at an early stage of optical design is the topic of paper [11]. Computer simulation using optical design software enables the optimization of optical parameters and selection of the most effective mathematical model as well as the equipment necessary for calibration. The issue of specular surfaces of objects is a very common occurrence in methods and technologies based on computer vision. In paper [12], numerous experiments performed on different shapes and sizes of specular surfaces of objects are described, with qualitatively and quantitatively reconstructed 3D profiles of different shapes of specular surfaces presented. A new method of measuring mirror surfaces that directly provides analytical solutions for three-dimensional points on a mirror surface is proposed in paper [13]. The technique of three-dimensional camera calibration based on two 2D camera calibrations was developed in paper [14]. A physical model is used to determine the exact locations of the calibration points. A significant issue in 3D reconstruction or creating 3D models from a set of images is often the need for large memory. In order to solve this issue as well as the issue of low efficiency of the algorithm for recognizing 3D objects, paper [15] proposes an algorithm for that purpose, which is based on enhanced point pair feature. In paper [16], a three-dimensional scene reconstruction based on binary space coding and decoding is proposed, with coding accuracy of up to 100% and the reconstruction result for the plane with an error of 0.0993 mm. Obtaining a three-dimensional textured model based on 2D-2D transformation on a distorted (warped) image is shown in paper [17]. Shape reconstruction is based on planar rectification and collation of laser profiles, and not on triangulation. The final paper [18] included in the second part of the scientific literature review proposes a method for reconstructing the two-dimensional profiles of ring-shaped objects using image processing, resulting in a point cloud consisting of outer and inner contours that can be directly used for automated measurement.

The third part of the scientific literature review is related to the application of computer vision or machine vision to problems in mechanical engineering, which is also the focus area of this paper. In paper [19], illumination compensation techniques were used to evaluate the ground surface roughness with regard to statistical texture parameters using machine vision. Three-dimensional surface roughness parameters are compared with texture parameters. Contouring errors of CNC machine tools are investigated in paper [20]. Binocular vision-based 3D method for detecting high dynamic and wide-range contouring errors of CNC machine tools has been successfully proposed. In paper [21], a vision system was developed to recognize turning inserts placed in a tool holder. The subject vision system recognizes 9 different types of inserts based on the insert angles, edge lengths and nose radii of each insert. A dimensional inspection system of shaft parts based on machine vision is proposed in paper [22]. Experimental results have shown that the measurement accuracy reaches 0.015 mm, i.e. 15 μm, which can be promising, but care should be taken about the appropriateness of the application in relation to the object dimensions. Paper [23] describes an improved 3D imaging (vision) system for dimensional quality inspection of long, flat-rolled metal products. Two-dimensional characteristics of rolled products - width and flatness are the focus of measurement. A simple three-dimensional measurement system based on machine vision was developed in paper [24]. In the case of hole diameters, the maximum error was 0.373 mm and the minimum error was 0.053 mm, which can meet one part of the tolerances used in engineering schematics. Tool positioning plays a significant role in the accuracy of manufacturing workpieces using CNC machine tools. The system for precise tool positioning and verification on turning and milling machines based on machine vision is presented in paper [25]. The developed system extracts the difference between the actual and target tool positions from the captured images through image processing and calculates the error, whereby the maximum positioning error observed was +/– 206 μm. Paper [26] presents a vision-based system for evaluation of surface roughness as well as quantitative and qualitative evaluation of surface texture. The results obtained using the vision-based system vary between 9% and 11% compared to the stylus-based ones. Detection and selection of bearing diameter based on machine vision system is the topic of paper [27]. After processing the images collected by the CCD camera, the bearing edge contour is obtained, on the basis of which the bearing diameter is detected and determined.

Considering the scientific literature review, it can be concluded that there is not a large number of papers that deal with the evaluation of the dimensions of workpieces in terms of determining their acceptability in view of the requirements set out in the technical drawing. This paper will conduct extensive research in terms of dimensional control of workpieces and list all the existing limitations of computer vision with regard to its application in this task.

2 PROBLEM FORMULATION AND RESEARCH OBJECTIVE

When considering the accuracy of manufactured components in mechanical engineering in relation to the requirements set out in the technical drawing, the following should be taken into account: absolute precision in component production is not possible due to limitations of regular production processes and/or excessive costs that are not economically justified. For this reason, the components are manufactured within the permitted variations or defined tolerances with respect to the nominal dimension values. The application of such production (within a certain accuracy limit) was first introduced in the manufacture of ammunition and weapons [28]. It was soon noticed that the quality of fits must be proportional to the dimension, i.e. expressed as a percentage of the dimension. For the practical application and proper functioning of machine components, the tolerances of the components in the fits are important, i.e. the components that form a joint through their abutting surfaces. According to the ISO system, the fundamental tolerance is determined, which strictly defines the range of the tolerance field in relation to the nominal value of the observed dimension, i.e. the area of nominal dimensions to which it belongs. After the manufacture of components, quality

control is performed, where the accuracy of the manufactured components is evaluated in relation to the requirements set out in the technical drawing. Classic devices for measuring tolerated dimensions include various types of calipers, micrometers, dial indicators and similar devices that involve contact between the device, the manufactured component and the person performing the measurement task. This approach takes up a lot of time, which often entails insufficient competitiveness in today's market. The focus of this research is on the possibilities of applying computer and/or machine vision in terms of verifying the acceptability of manufactured components.

As soon as computer vision is mentioned, it immediately becomes clear that acquisition and processing of digital images is paramount. Digital image is created through several phases, which are described below and shown in Fig. 1.

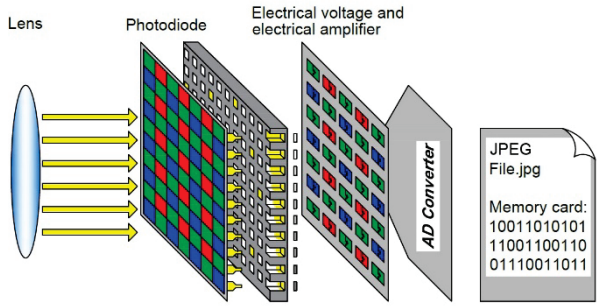

Figure 1 Creation of a digital image

After the light passes through the lens, it reaches the photodiodes on the sensor (usually CCD and CMOS sensor) which convert the energy of the incoming photons into the appropriate charge. That electric charge is converted into voltage, which is then amplified by a power amplifier. The amplified voltage is processed by an A/D converter that converts the analog signal into a digital recording. Finally, the processor processes the obtained digital recording using a series of complex operations (interpolation, focusing, noise reduction, compression …), after which the processed image is recorded on a memory card. Since the aim of this paper is to evaluate the dimensions of a workpiece, the camera sensor plays a very important role because it determines the number and quality of pixels in the image, which are the only repetitive elements on which the evaluation is based. The lens also has a very important role since it should ensure adequate projection and zooming of the workpiece in order to occupy as large an area of the digital image as possible. All variables on the basis of which the dimensions, i.e. the acceptability of the workpiece will be evaluated are based on measuring the properties of the image regions of accurate and defective workpieces according to the principles explained in Fig. 2. The left frame of Fig. 2 shows the sensor and edge of a workpiece with black lines and yellow lines that represent the maximum and minimum tolerated dimension of the workpiece. The middle frame contains the ideal appearance of the workpiece shown in the image (green pixels), and the right frame indicates the tolerated pixels when the maximum and minimum values of the workpiece dimensions are taken into account. In the right frame, each pixel on the outside of the yellow lines, if activated directly, means that the workpiece is defective. The research in this paper will be based on stator acceptability evaluations, which are also a part of a project funded by the European Regional Development Fund under code KK.01.2.1.02.0062. The main activity of the project is the development of new innovative products, namely a quality control machine and a palletizing machine in the automotive industry. Various sizes of stators and rotors will be checked for correctness on the quality control machine.

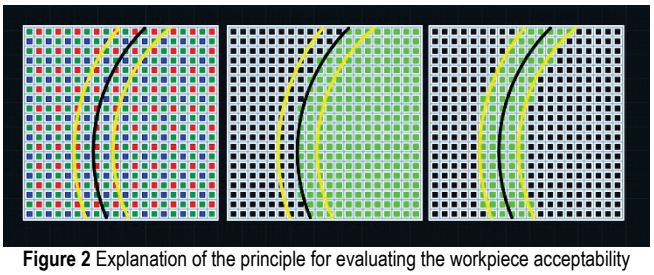

Figure 2 Explanation of the principle for evaluating the workpiece acceptability

In this regard, the input variables described below and extracted from stator digital images will be used to evaluate the acceptability of each stator. Since the aforementioned project (project code: KK.01.2.1.02.0062) has several phases, this paper will present only the first phase of research, with the conclusion containing guidelines for future research.

2.1 Description of Input Variables Used to Evaluate Acceptability

The input variables that will be used to evaluate the acceptability of the workpieces (stators) are based on measurements of the properties of the image region or regions. Therefore, the areas (regions) of the image, which in this case include the workpiece or blurs (impurities), have properties such as surface area, center of mass, orientation, bounding box, etc. The first steps in processing the workpiece image are reduced to obtaining a black and white image and removing all possible stains (impurities) that can arise due to various factors.

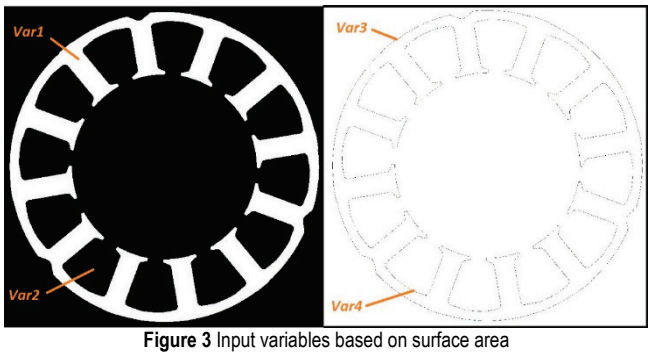

Figure 3 Input variables based on surface area

The first four input variables are based on the surface area or pixel count of the region of interest, i.e. the stator. The first input variable Var1 represents the number of pixels from

the stator drawing, the second variable Var2 represents the number of pixels of the stator hole, the third variable Var3 represents the number of pixels that make up the outer stator edge, and the fourth variable Var4 represents the number of pixels that make up the inner stator edge, as shown in Fig. 3.

The fifth and sixth variable (Var5 and Var6) represent the maximum width and height (measured in pixels) of the stator. The seventh variable Var7 is defined by the number of pixels that make up the surface area of a solid convex hull (polygon) containing/including a stator. The ratio of the surface area of the region (stator) and the surface area of the solid convex hull (polygon) represents the eighth variable Var8, and the ratio of the surface area of the region (stator) and the total surface area of the bounding box represents the ninth variable Var9.

3 APPLIED METHOD - FUZZY C-MEANS CLUSTERING

The Fuzzy C-means clustering method will be used to evaluate the dimensional acceptability. The idea is that multi-dimensional data points consisting of the previously described variables provide sufficient qualitative and quantitative indicators so that the set of all data points can be observed through two clusters. One cluster represents data points that are related to accurate workpieces, while the other cluster represents data points that are related to defective workpieces. A certain peculiarity of Fuzzy C-means clustering is that each data point can belong to a larger number of clusters with a certain membership degree, while the sum of all memberships in different clusters must be equal to 1.

The set of data points X to be clustered can be specified in the form of a set:

$$X = \{x_1, x_2, x_3, \ldots x_N\} \tag{1}$$

Each point x_i is a vector which has a number of dimensions equal to the number of input variables and represents the quantitative features of the i workpiece.

3.1 Fuzzy C-means Clustering Algorithm

Mathematical algorithm of Fuzzy C-means clustering consists of the steps described below.

1. There are n data points set to be clustered x_i, where $i = 1, 2, 3, \ldots n$.
2. Initiate the wanted number of clusters k by meeting the following condition $2 \leq k \leq n$.
3. Define the fuzziness of the cluster marked with f, where $f > 1$. f is a fuzzy partition matrix exponent for controlling the membership degree. Fuzzy overlap refers to the blurred fuzzy boundaries between the clusters, i.e. to the number of data points which are characterized by significant membership in more than one cluster.
4. Initiate the fuzzy partition matrix $\boldsymbol{U}$ which has the dimension of $n \times k \times m$. In the iteration, this matrix should be defined by coincidental values of membership, while meeting the conditions set out below.
   a) $\boldsymbol{U}_{ijm} \in [0,1]$ and
   b) $\sum_{i=1}^{n} \boldsymbol{U}_{ijm} = 0$ for each i and fixed value of iteration m.
5. Calculate the cluster centers using the following formula

$$C_{jm} = \frac{\sum_{i=1}^{n} \boldsymbol{U}_{ijm}^{f} \times x_{im}}{\sum_{i=1}^{n} \boldsymbol{U}_{ijm}^{f}} \tag{2}$$

where j represents the cluster, and m represents the algorithm iteration.

6. Calculate the Euclidean distance

$$D_{ijm} = \left\| \left(x_{im} - C_{jm} \right) \right\| \tag{3}$$

where i represents the data point, j represents the cluster, and m represents the algorithm iteration.

7. Update the membership matrix $\boldsymbol{U}_{ijm}$ with new membership values by using the following formula:

$$\boldsymbol{U}_{ijm} = \frac{1}{\sum_{i=1}^{n} \left(\frac{D_{ijm}}{D_{ikm}} \right)^{\frac{2}{f-1}}} \tag{4}$$

Formula set out above is applied only to data points where $D_{ijm} > 0$. If $D_{ijm} = 0$, the membership is full and the value is initiated with 1.0.

8. Repeat steps 5 to 7 until the maximum value of difference of all members of matrix $\boldsymbol{U}_{ijm}$ of the current and previous iteration is higher than the algorithm stopping criterion ε or until the maximum set number of iterations m is performed.

4 DESCRIPTION OF THE EXPERIMENTAL RESEARCH CONDUCTED

Experimental research, i.e. acquisition/recording of digital images was carried out on a machine prototype that is being developed within the aforementioned project under code KK.01.2.1.02.0062. Fig. 4 shows a prototype machine for quality control of finished products of smaller dimensions. Quality control, that is, dimensional acceptability evaluation on this machine was related to stators and rotors.

The machine prototype incorporates the components indicated below that are essential for computer vision and ultimately for the acquisition of digital images of products being controlled. An Allied Vision industrial camera model Alvium 1800 U-507 and a bi-telecentric lens model TC23085 from Opto Engineering are used for the acquisition. Two Alvium 1800 U-507 cameras and two TC23085 lenses are

visible on the left, and their detailed view is given on the right side of Fig. 4.

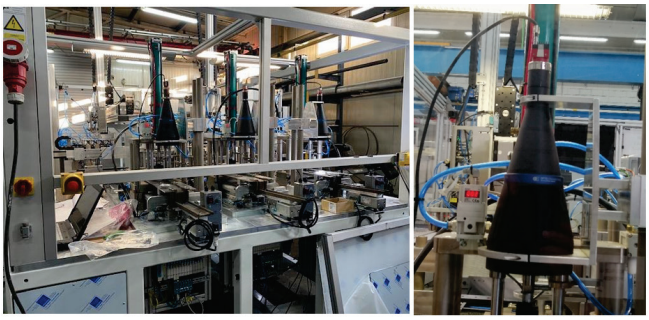

Figure 4 Machine prototype for quality control of finished products

The backlight from model LED1-FL-83×75 manufactured by GETCAMERAS was used to illuminate the workpieces when acquiring digital images. Fig. 5 shows the illumination with a sketch of the entire system that includes the camera and the lens.

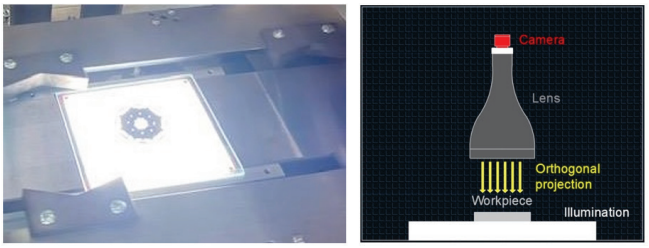

Figure 5 Illumination and sketch of the acquisition system

The basic technical specifications of the camera and lens are given in Tab. 1.

Table 1 Basic technical specifications of cameras and lenses incorporated in the prototype

Camera Alvium 1800 U-507		Lens TC23085	
Interface	USB3 Vision	Magnification	0.104
Resolution	2464(H) ×2056(V)	Image circle ∅	11 mm
Spectral range	300 to 1100 nm	Max detector size	2/3″
Sensor	Sony IMX264	Working distance	279.9 mm
Sensor type	CMOS	wF#	8
Shutter mode	Global shutter	Telecentricity typical (max)	< 0.02 (0.04)°
Sensor size	Type 2/3	Distortion typical (max)	0.02 (0.08)%
Pixel size	3.45 × 3.45 µm	Field depth	62 mm
Lens mounts	C-Mounts, CS-Mounts	CTF @ 70 lp/mm	> 45%
Max. frame rate at full resolution	34 fps at ≥ 200MByte/s Mono8	Object field of view with 2/3″ - 5 MP detector (8.50 × 7.09)	81.73 × 68.17 mm
ADC	12 Bit		
Image buffer (RAM)	256 KB		
Non-volatile memory (Flash)	1024 KB		

Using this machine prototype, an experimental research was conducted on 115 specimens of stators shown in Fig. 3. Using the equipment shown, 115 digital images of all specimens were acquire, of which 12 samples were defective. Using the digital images, 9 different features were quantified that will represent the input variables for the fuzzy inference system of C-means classification. Prior to quantifying features from digital images, all digital images were converted to binary or monochrome format and cropped to a size of 1850 × 1850 pixels. The matrix of each digital image had 1850 rows and columns (Fig. 3). The stator was placed in the center of the image after cropping, and a small area was reserved for the unnecessary surroundings in relation to the maximum height and width of the stator.

5 RESULTS OBTAINED

The input/output data set consists of 9 input variables and an output variable that can take only two values - 1 or 2. A value of 1 represents an accurate specimen, while a value of 2 represents a defective specimen. The accuracy of all specimens used in this study was verified using a measurement matrix. Out of a total of 115 records of input/output experimental data, 98 records were used for training and 17 for testing the fuzzy inference system of C-means classification. Random selections of input/output data for training were generated based on the criterion of the smallest root mean square error obtained. The condition for random selection of input and output data for training is that the root mean square error must be less than 0.14 in the training phase or the time spent to detect it must not exceed 4 hours, i.e. 14400 seconds.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}\left(mesured(Out)_i - systematic(Out)_i\right)^2}{n}} \quad (5)$$

where: n - number of specimens (different stators or their digital images), *measured(Out)* - value of specimen accuracy determined using the measurement matrix, and *systematic(Out)* - value of specimen accuracy obtained through the fuzzy inference system of C-means classification.

Five different fuzzy inference systems of the C-means classification were generated. For the first system the first four input variables and the output variable were taken, in the second system the first six input variables and the output variable were taken and so on up to the fifth fuzzy inference system, where all nine input variables and the output variable were taken. Since the fifth and sixth input variables represent the width and length of the stator, the second system is expanded with two input variables, and all thereafter are expanded with one input variable.

Tab. 2 indicates the root mean square errors in the training phase and the testing phase for all five fuzzy inference systems of the C-means classification.

Table 2 Root mean square error for the training and testing phase

	FIS_1	FIS_2	FIS_3	FIS_4	FIS_5
$(RSME)_{Training}$	0.1393	0.1397	0.1347	0.1244	0.1336
$(RSME)_{Testing}$	0.1570	0.1542	0.1417	0.1149	0.0737

Whichever of the five fuzzy inference systems generated is placed into focus, with graphs indicating the dependencies of the input variables on the output variable, three different dependencies arise. Fig. 6 contains graphs indicating the dependencies of the input variables on the output variable. Even though the generated fuzzy inference systems have more than two input variables, only two input variables with an output variable can be placed on 3D graphs. The figure below contains 3D graphs with combinations of input variables covering the aforementioned dependencies between the input variables and the output variable, where linear or segmentally predominantly linear dependencies between the input variables and the output variable prevail. Most often in the case of the first and second input variables with the output variable a somewhat more complex dependence occurs.

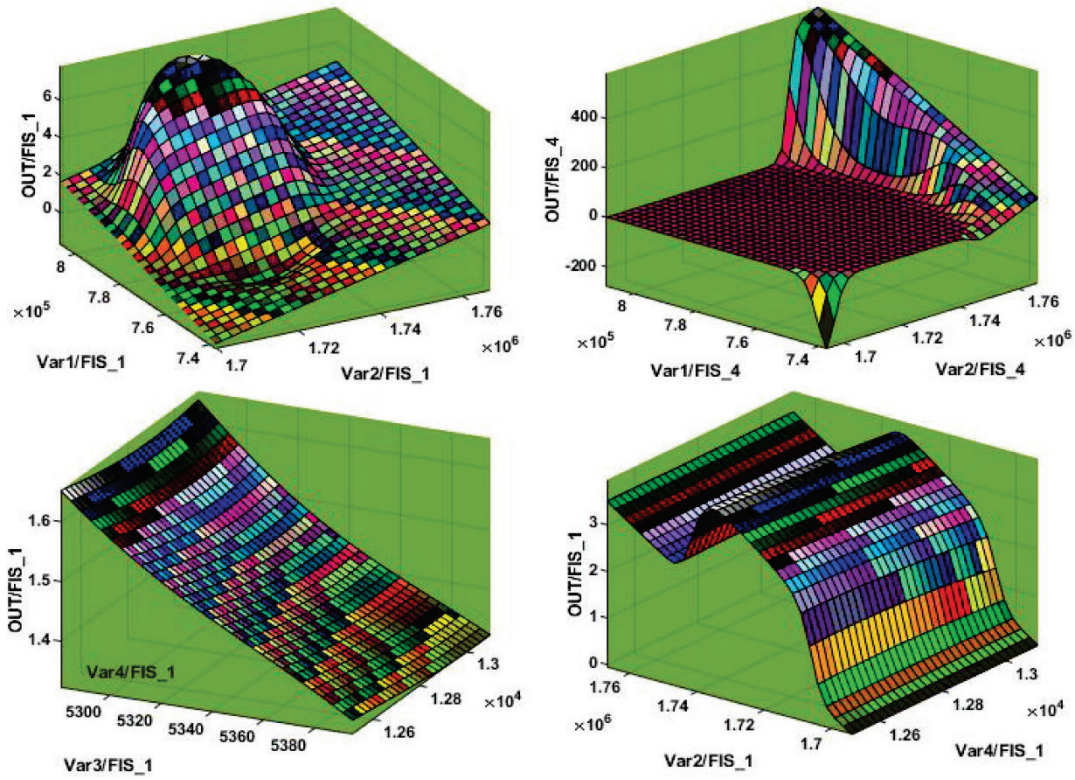

Figure 6 3D graphs of dependencies of the input variables on the output variable

Another important observation that should be noted in the obtained results is that the mathematical rotation (rotation of members in the digital image matrix) of the stator in the digital image causes significant changes in the edge delineation.

Figure 7 Enlarged views of the rotated and non-rotated image

Fig. 7 shows enlarged views of the same edge of a rotated and non-rotated image, where the aforementioned changes can be observed.

The final significant observation to be presented herein relates to the dependence of certain variables on the stator orientation angle. During the acquisition of digital image, each stator is oriented differently with regard to the position of the grooves located on the outside, with the angles between them amounting to 120°. The following graph indicates a significant correlation of Var3, Var4, Var5 and Var6 with the angle, i.e. orientation of the stator.

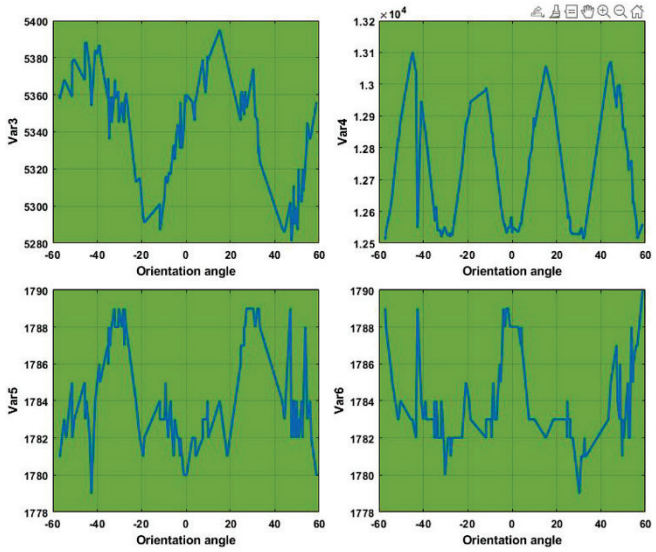

Figure 8 Dependence of orientation on the input variables

6 CONCLUSION AND DISCUSSION

This research is the first step in finding a satisfactory solution for evaluating dimensional accuracy using computer vision. In this research, a number of limiting factors were discovered that should be taken into account when planning to use computer vision to evaluate the dimensional accuracy of workpieces. The first limiting factor relates to the precision up to which the dimensional accuracy of workpieces can be evaluated with regard to economic justification and technical feasibility. Precision of 0.1 mm, i.e. 100 μm is sufficient to evaluate the dimensional accuracy of the stator that was used as a specimen in this paper. The camera used has a resolution of 5.066 MP and a pixel size of 3.45 × 3.45 μm when the area of the image is equal to the size of the built-in sensor of 2/3, i.e. 8.50 × 7.10 mm. As the digital image almost always shows a larger area, the basic building block of a pixel has much larger dimensions, i.e. the larger the workpiece, the lower the accuracy. In the case of stators with a maximum dimension equal to 60.2 mm, each pixel when recalculated has a size of about 33 × 33 μm, i.e. 3 pixels make 0.1 mm. If one of the more precise sensors is taken into focus (model: Canon LI8020SA CMOS), which has the following features: a resolution of 250 MP (19568h × 12588v) pixels and a sensor size of 29.35 × 18.88 mm, or pixel size of 1.5 × 1.5 μm, it can be concluded that for a workpiece that fits in a square measuring 100 × 100 mm, the size of the recalculated pixel should ideally be about 7.5 × 7.5 μm. From the above it can be concluded that the application of machine vision for evaluating the dimensions of workpieces is very limited to a small range of products and precision that is at least ten times lower than with the conventional hand-held measuring devices. To evaluate the acceptability of the stator dimensions in this paper with respect to the obtained root mean square error, it can be concluded that a camera with a higher quality sensor of much higher resolution is definitely required.

The lens has a significant role in the issues of estimating the acceptability of the workpiece dimensions. The lens must have an orthogonal or parallel projection and the largest possible area that can be projected onto the sensor without large distortions and differences in the projected size displayed by the pixel with respect to the distance between the center of the workpiece and the projected area. Furthermore, the size of the projected area significantly reduces the range of different products that are suitable for the application of machine vision.

After successfully resolving the aforementioned limitations, there are several other limitations related to the processing of the obtained digital image. One of the most significant limitations is indicated in Fig. 7. If digital image is rotated mathematically, the cascaded continuity of the edges is destroyed and the total number of pixels from which the projection of the observed objects is constructed changes. This limitation hinders the overlap of the tested items with the accurate workpieces on the differences of which much better quality input variables would be generated than those of one-dimensional significance presented in this paper. Since the mathematical rotation causes a number of adverse effects, the control of orientation of test specimens becomes a key issue, regardless of whether it is solved by design of a machine vision system or planned generation of a database to be used in the training and testing phase of a model for evaluating dimensional acceptability. Furthermore, another important finding regarding the orientation of the observed workpieces relates to the existence of dependencies between certain variables and orientation angle as shown in Fig. 8. For variables Var5 and Var6, it is intuitively clear why there is dependence because there are three properly spaced grooves on the exterior side, but there is no simple explanation for variables Var3 and Var4. As for the type of dependence of input variables on the output variable, the linear and segmentally predominantly linear dependencies that prevail indicate to a simple and stable correlation that ultimately has a positive effect on mapping the input into the output area. Through the review of the literature, a small number of articles dealing with this issue were found, therefore it is considered that this research can provide good guidelines for future research. This research did not provide a solid solution, but it outlined the issues while defining the main limitations and research directions.

Future research could be conducted by creating more meaningful input variables with one-dimensional as well as two-dimensional correlations expressed through the value of each variable. Solutions related to the control of the orientation of workpieces, whether they are structural or of some other framework, are certainly one large area within which various research can be conducted. An appropriate orientation control solution would open up a series of other possibilities, from creating input variables resulting from differences in the overlap of workpieces, to the creation of databases containing generic workpieces or generic forms that would be used for comparison. Future papers dealing with the aforementioned topics would probably find interested readers.

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Authors' contacts:

Ilija Svalina, PhD, Assistant Professor
(Corresponding author)
University of Slavonski Brod, Mechanical Engineering Faculty in Slavonski Brod,
Trg I. B. Mažuranić 2, 35000 Slavonski Brod, Croatia
E-mail: isvalina@unisb.hr

Dražen Turinski, Assistant
University of Slavonski Brod, Mechanical Engineering Faculty in Slavonski Brod,
Trg I. B. Mažuranić 2, 35000 Slavonski Brod, Croatia
E-mail: dturinski@unisb.hr

Ivan Grgić, PhD, Postdoctoral Researcher
University of Slavonski Brod, Mechanical Engineering Faculty in Slavonski Brod,
Trg I. B. Mažuranić 2, 35000 Slavonski Brod, Croatia
E-mail: igrgic@unisb.hr

Sara Havrlišan, PhD, Assistant Professor
University of Slavonski Brod, Mechanical Engineering Faculty in Slavonski Brod,
Trg I. B. Mažuranić 2, 35000 Slavonski Brod, Croatia
E-mail: shavrlisan@unisb.hr

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A Study on The Wireless Remote Safety Measurement Device for Structures based on Multi-Waterproof Sensors

Chang Jin Yang

Abstract: Recently, as the need for constant safety management increases due to collapse accidents caused by external displacement of buildings, it is necessary to manufacture a construction ground gradient meter and serial open information technology (IT) sensor that can be monitored wirelessly based on epoxy resins, polyvinyl chloride (PVC) pipes, and communication cables. In particular, waterproof performance is required for ground monitoring of underground spaces with water, and for this purpose, research was also conducted to double mold the inside of the incline system. Construction IT convergence's building slope measurement device technology can respond to safety accidents by checking the amount of change in building displacement through a real-time online monitoring system. In addition, it is an industry with various application markets by converging IT technology into the existing construction industry and can be used as a pre-quake detection monitoring system for structural collapse accidents caused by external displacement. Therefore, it is intended to secure a sustainable facility safety management system through research in the field of real-time measurement technology on various facilities and surrounding ground behavior.

Keywords: multi-waterproof sensors; safety; structure; real-time online system; wireless remote

1 INTRODUCTION

1.1 Research Background and Need

It is difficult to manage the safety of the structure with the field measurement method that has been previously implemented about once a week. In order to prevent accidents in advance, real-time safety measures at the site by permanent measurement management are necessary [1]. Civil and building structures need continuous maintenance during and after construction, and the need to establish a permanent safety monitoring system in preparation for changes in social environment and disasters (Floods, typhoons, earthquakes) is emerging [2].

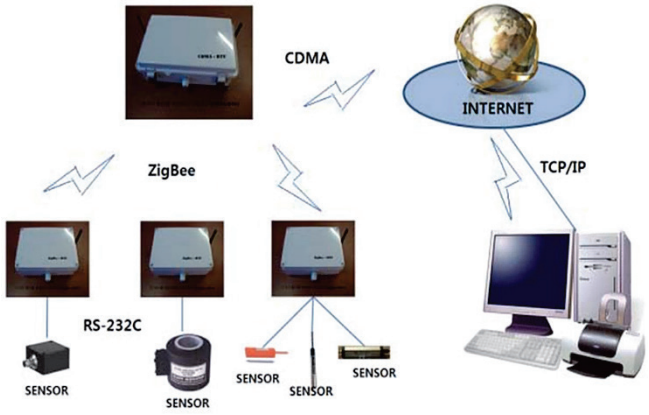

Figure 1 Conceptual map for remote sensing

And soil barriers have been preparing for detailed rules such as tunnels, bridges, dams, nuclear power plants, and pardons disaster, and the Earthquake Disaster Prevention Act has been implemented first for government offices since 2010 [3]. Safety diagnosis of facilities in South Korea relies on visual inspection or inspection using diagnostic equipment (Safety check: 2 times/year, Precision check: 1 time/2 years). In addition, there are limitations in active facility safety management, such as difficulty in accessing facilities during inspection, raising the need for a permanent installed safety monitoring system [3].

Therefore, in order to analyze the safety status of the structure and measure displacement, we intend to study a management program that remotely controls measurement data in real time by standardizing data analysis and measurement methods using wireless measurement terminals and upgrading measurement devices. Fig. 1 is a conceptual diagram of remote measurement.

1.2 Current Status of Measurement Management Methods in Korea

In most sites in Korea, manual measurement methods are mainly applied, in which a technician directly puts a sensor into a measurement position installed underground and then pulls it upward to measure the slope of the slope. Usually, reports are prepared and managed based on data regularly measured by underground slopes installed at major points and field managers judge the stability of structural stones based on the measurement reports and visually check the displacement and deformation of nearby buildings [4].

Since these manual measurements are directly measured by humans, there is a limit to the reduction in the frequency of measurement in relation to the increase in labor costs, making it difficult to recognize abnormalities and respond immediately. In addition, survey errors may occur depending on environmental changes and technician proficiency, and it is difficult to obtain continuous data due to the influence of field conditions, weather changes, and frequency of measurement. Real-time measurements shall be made in the field to prevent damage caused by large accidents and recently, automatic measurement technology is applied as an alternative to compensate for the weaknesses of manual measurement technology and ensure the continuity and reliability of measurement data. As shown in Fig. 2, the existing automatic measurement technology connects

sensors inserted inside the incline tube to the data logger through data measurement lines and transmits measurement data through wireless communication devices, allowing administrators to check the displacement of dirt barrier facilities [5, 12].

However, as the number of sensors to be installed increases according to the measurement depth, a number of measurement lines are used to connect each sensor to the data logger, which causes problems of limiting the measurable depth or increasing the diameter of the slope.

Conversely, when connected to the outside of the inclined system pipe, the measurement line may be disconnected, and a leakage problem may occur while being connected to a sensor inside the inclined system pipe. In addition, existing data logger equipment is expensive and power cables are required to build data loggers and wireless communication devices as system elements, and unit system (Combination of data logger and communication device) components are bulky, making it difficult to install and maintain on-site.

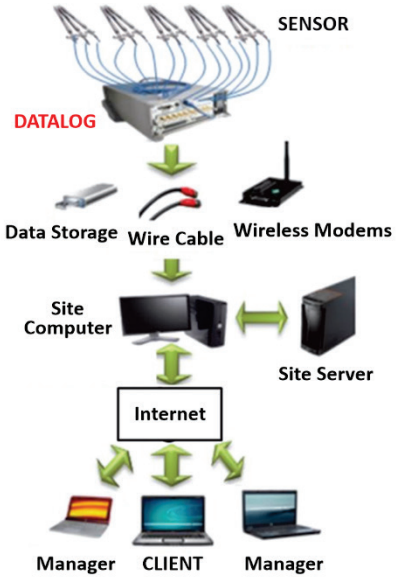

Figure 2 Conceptual diagram of the automatic measuring system currently used

1.3 Current Status of Overseas Related Technologies

As shown in Tab. 1 overseas companies are divided into sensor manufacturers and specialists that manufacture and distribute each sensor element technology as a unit system, and each unit system is composed of standardized equipment for measurement purposes, so it does not actively accept users' technical requirements. In the case of overseas shipping countries, it is being developed focusing on disaster response and structure maintenance such as earthquakes using ubiquitous technology (RFID Tag) to detect vibrations caused by earthquakes, transmit data and minimize damage to buildings themselves.

In the future, it is under development as a system that controls overall risk factors by monitoring various fields such as acceleration, deformation, temperature, light, sound and measurement.

Table 1 Current status of overseas measurement technology

Category	Content
Tunnel data management	- Systematization of basic tunnel data necessary for tunnel maintenance and management - Systematization of history management for maintenance and reinforcement necessary for maintenance
Measurement	- The construction of the pole tunnel is carried out in real-time monitoring by performing automatic measurement overall - Temporary measurement is carried out at the same level as in Korea, and systematization is possible to collectively process data organization of measurement results
Safety diagnosis and evaluation	- Properly carry out the initial inspection items for safety diagnosis - Establish an evaluation system so that it can be an objective evaluation - Development and application of techniques that can perform quantified evaluation
Integrated maintenance	- Developing a system that collectively manages tunnel construction to public training after completion - Developing a system that can comprehensively perform maintenance
Measuring equipment	- Development and use of automatic measuring sensors with proven durability and precision - Use data logger development with proven durability and precision

According to the characteristics of measurement systems at home and abroad, there is a need to develop a new wireless remote measurement technology that can be efficiently used in construction sites.

2 TECHNOLOGY MECHANISM

With the recent development of communication-broadcasting technology, a high-speed network environment and high-performance-miniature terminals have emerged, creating an environment where safety management is possible at all times. By combining such communication technology, it is possible to economically operate and manage real-time monitoring systems that can measure and manage temporary facilities and structures at all times by wirelessly transmitting measurement data of soil membrane displacement. Based on these environmental changes, it was judged that if the technology was improved in the following respects, the problems and limitations of the existing measurement management technology could be solved. The main research and development matters are as follows:

- Application of a high-resolution gradient sensor to improve reliability of measurement.
- In order to improve the workability of multi-faceted sensors, the development of an inclined meter sensor that can be extended according to the measurement depth and is easy to install on-site.
- Power supply other than wired cables to improve workability and maintenance of wireless remote measuring devices.
- Simplification of unit system (data logger + communication device) components to facilitate construction and maintenance.

- Development of a monitoring system that can collect and analyze measurement data in real time and is easy to use and maintain.

The conceptual diagram of the new wireless remote measurement management applied by reflecting the technology improvement points of the above contents is shown in Fig. 2. It is believed that this will be used to realize the advancement of safety management in the actual field.

2.1 A Study on Real-Time Wireless Remote Measurement Using Multi-Waterproof Washing Machine

A wireless remote management program for gradient measurement was developed to evaluate the stability of the structure, and as shown in the conceptual diagram of program development in Fig. 3, a DB and server management program that can manage data transmitted from sensors to sub and a client program that allows customers to check measurement results at all times.

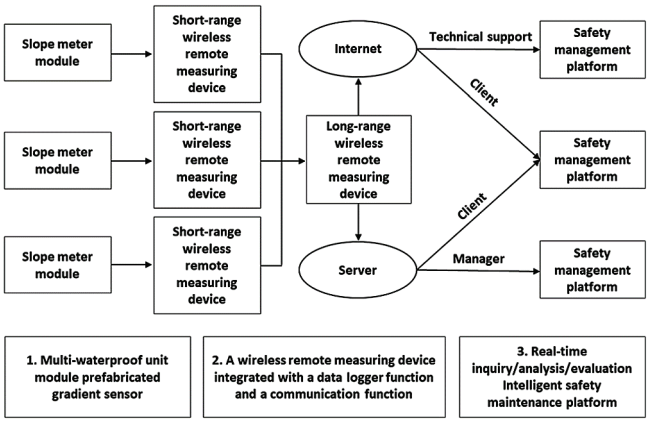

Figure 3 Improved wireless remote measurement management process

There are Global Monitoring technologies and Local Monitoring technologies to measure changes in the dynamic behavior of structures using sensors such as accelerometers, speedometers, displacement meters, stress gauges, ground-reaction meters, and anemometers. Global Monitoring is a monitoring and maintenance system for the overall behavior of the structure and Local Monitoring is divided into monitoring and maintenance systems for the stability of each member of the structure, such as columns and beams [6]. In addition, it is intended to develop a multi-waterproof sensor for displacement monitoring that can measure the curvature and sagging of a structure using a Micro Electromechanical System (MEMS) gradient chip and to study a wireless remote measuring device that wirelessly collects data from a long distance [7]. In the structural design phase, the assumption, idealization and simplification of the material properties and analytical models inevitably include actual structure behavior and significant errors. Therefore, interpretation and evaluation techniques based on instrumentation data are required and a level-specific alarm and maintenance system of structures can be built based on these interpretation and evaluation techniques. Therefore, structural analysis technology, field measurement data analysis technology and comparison and analysis technology of analysis results and measurement results are established [8].

The simplest way to determine the existence of safety by comparing and analyzing the measurement results is to make a judgment in accordance with the relevant standards and if there are no related standards, it is necessary to establish the criteria by consulting with relevant technical data and related experts. The operation management system develops a monitoring program to store measured values from sensors and to enable users to check instrumentation data in real time according to established criteria [9]. The user can set the required level of management values step by step and the program notifies the user step by step when data is detected that exceeds the management values set by the user. It is reflected in the program to prevent unexpected accidents by sending text messages to the mobile phone in the absence of users [10]. Therefore, the most important safety assessment algorithm is developed and reflected in the operations management system to inform the user of the current structure status.

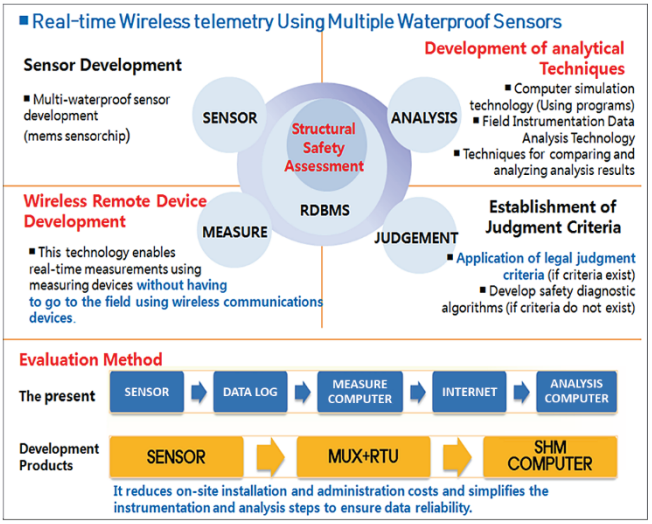

Figure 4 Concept of real-time wireless remote measurement using multiple waterproof sensors

2.2 A Research on Multi-Waterproof Sensor and Wireless Remote Measuring Device

This research is a technology that can overcome the limitations of existing automatic measurement technology, construction and maintenance for structure safety management, and significantly improve the reliability, site constructability and economic feasibility of measurement results. As shown in Fig. 4, like the concept diagram of sensor development for displacement monitoring, puts a sensor in the inclinometer tube and manufactures a multi-station inclinometer sensor that is waterproof with double molding as a unit module to enable assembly in the sensor can be assembled in the field. Therefore, it is a wireless remote safety management operation system that manages the safety status of the facility in real time by connecting multiple sensors in series and open lines to near-field and

remote measuring devices that incorporate data logger functions and communication functions. The system is planned to be developed for use in the safety management of various structures by connecting various sensors to wireless remote measuring devices and the main contents of the development system are summarized as follows.

It developed a multi-waterproof sensor for displacement monitoring that improves waterproofing performance through multiple molding of MEMS chips, and studied multi-waterproof sensor for displacement monitoring that improves waterproofing performance by using a double molding method on MEMS gradient sensor chips.

In addition, we simplify system configuration by developing near- and far-field wireless remote measuring devices that integrate data logger functions and communication functions. In order to improve economic feasibility with near- and long-distance radio remote measuring devices, NFC remote measuring devices (telecommunication free) and remote radio remote measuring devices (telecommunication fee paid) were researched. Existing automated measuring technology often caused difficulties in measuring data due to waterproofing problems by putting the primary molded incline inside the incline and connecting a number of measurement lines to the data processing unit. To solve these problems, the inclinometer sensor board is assembled in a small tube and the primary molding is performed. And it was able to improve waterproofness and durability by putting it inside the inclinometer tube and molding it once more. In the case of existing automated instruments, as shown in Fig. 4, when multiple sensor measurement lines were connected individually to data processing units by parallel and multiple wires, there was a high possibility of waterproof problems, communication line disconnection, and poor workability. And, in the case of multi-station inclinometer sensors, each communication line shall be connected through the inclinometer tube to the data processing unit. Therefore, many communication lines must be installed in the tube during multi-station measurement, so the depth of measurement was limited due to poor workability, waterproofing problems and increasing the section size of incline pipes [11].

To solve this problem, this research connects a multi-station inclinometer sensor made using a high-resolution MEMS sensor chip to a wireless remote measuring device in series and open lines. Connectivity defects are, first, not limited in depth of measurement and secondly, highly construct and thirdly, high-resolution sensor chips are used to ensure excellent economic, constructability and reliability. In addition, looking at the result values measured by the currently developed incline sensor, it is difficult to trust the measurement values because the measurement result values according to the temperature difference between Fig. 5 and night and day differ by about 2 cm. Construction sites using this make it difficult to trust the measured values converted into displacements. To solve this problem, a high-resolution MEMS sensor chip was used to study the displacement monitoring sensor with excellent performance that is not affected by temperature changes. Therefore, most sites that perform real-time monitoring by converting to displacement using the slope of an inclinometer sensor cannot trust the measured value. To address this problem, we develop a sensor for displacement monitoring with excellent performance that is not affected by temperature changes using a high-resolution MEMS sensor chip.

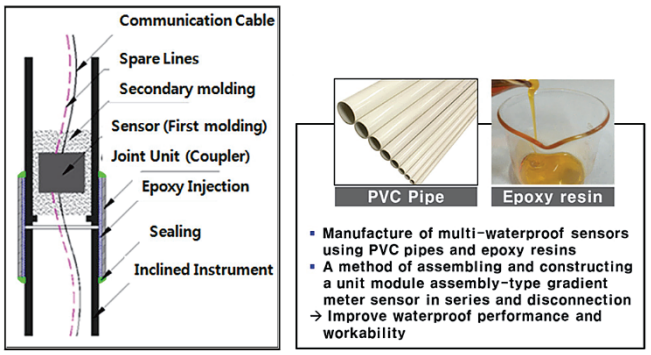

Figure 5 Composition of multiple waterproof sensor and wireless remote measuring device unit modular inclinometer sensor

As shown in Fig. 6, the unit all-type incline sensor is an integrated sensor-type incline sensor manufactured by inserting a resolution sensor into the incline tube of a predetermined length to facilitate assembly in the field and double molding the inside of the incline tube to improve waterproof performance.

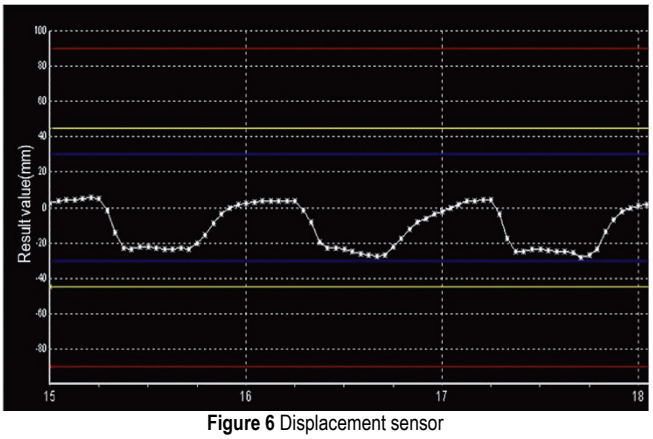

Figure 6 Displacement sensor

High resolution sensor application applied a high-resolution gradient measurement sensor chip of 0.00175 degrees, which can accurately measure the displacement of the structure, to ensure data reliability. This shows a higher resolution than 0.0023 degrees, which is the resolution of the sensor applied to the manual measurement, and 0.095 degrees, which is the resolution of the standard specification. As illustrated in Fig. 6, the unit model-type gradient sensor is manufactured by molding a sensor board manufactured using a high-resolution gradient measurement sensor chip in a small tube, and then putting it back in the gradient tube.

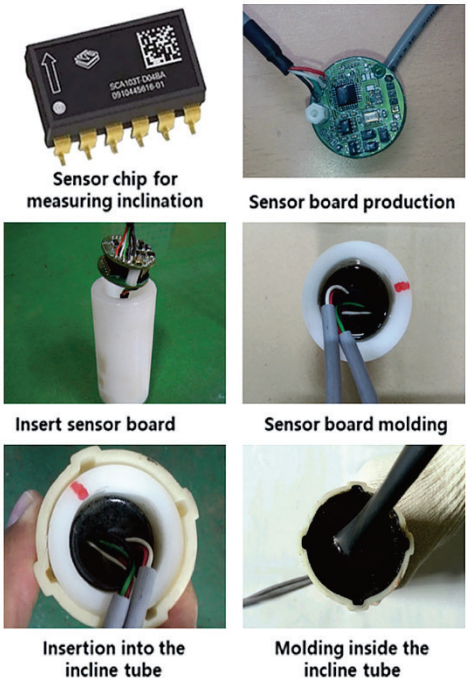

Figure 7 Unit modular incline meter sensor production

At this time, the durability and waterproof performance of the incline meter sensor were secured by double molding treatment including cable connection parts between sensors. Serial open circuit connection between sensors is manufactured such that a multi-view sensor and one data processing device are connected in series so that data can be transmitted to each other, so that multiple sensors can be connected regardless of the diameter of the incline tube. The unit modular gradient sensor connected in series can be extended in length through simple field assembly, making it easy to respond according to the measurement depth.

2.3 Network Configuration Using a Wireless Remote Measuring Device

The wireless remote measuring device applied to this technology integrates a data logger function and a communication function, and is a device that transmits measurement data recorded in the data logger using a near-distance wireless network. The network can be configured and operated by receiving data transmitted from a short-range network from a long-distance wireless integration device and transmitting it to a web server using a short-range wireless remote integration device without communication fees.

Fig. 8 shows the situation in which the displacement of the earth barrier wall is monitored using the measurement management system. A user can verify the data automatically measured according to the setting cycle and transmitted to a web server through the measurement management system and determine the stability of soil barrier facilities in real time using the automatic notification function for sudden displacement.

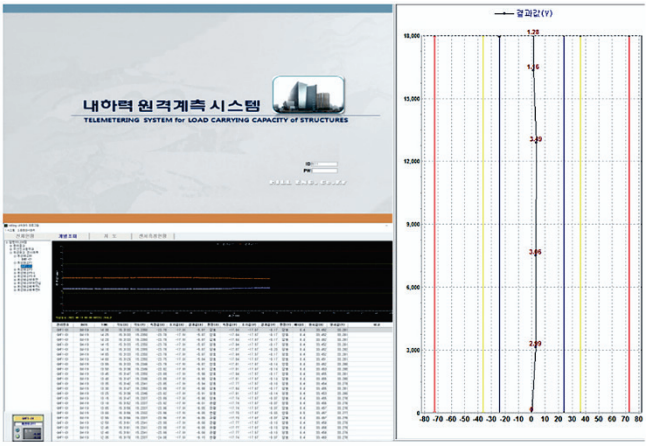

Figure 8 Measurement management system

2.4 Using a 3d-Mems-Based Gradient Sensor Chip for Displacement Monitoring

MEMS (Micro Electro Mechanical System) is a system that integrates micro-unit mechanical structures and electronic circuits using semiconductor process technology. Because silicon is mainly manufactured on substrates, signal processing circuits and MEMS devices can be manufactured on the same chip, which can minimize the impact on the surrounding environment due to low noise and small size. Because it is easy to manufacture sensors and can be manufactured through a batch process, price of development devices has a low advantage.

MEMS technology is similar to semiconductor technology, but each 3D microstructure manufacturing process and application system has unique design and manufacturing technology. Therefore it is difficult to standardize, so it is a technology that is used in various types of small-volume production (Application: Sensor, RF, Bio) in various application fields.

2.5 Sensor Features for Displacement Monitoring

- Using 3D-MEMS-based inclinometer sensor chips-High precision and small manufactured using semiconductor process technology
- Sensing function and RS485 communication embedded sensor
- Measuring ranges: ±15° (SCA103T-D04)
- Resolution: 0.0012° (10 Hz BW, analog output)
- Damped Frequency Response Rate: –3 dB 18 Hz
- Shock durability: 20,000g
- Excellent stability not affected by changes in ambient temperature
- Use differential measurement principles to reduce measurement errors and noise
- Power: DC 12 V

2.6 Development of Near-Range Wireless Remote Measuring Device with Integrated Data Logger Function

The traditional data processing method is to measure data using a data logger (Usually 18 or 36 channels are used

as data processing units) wired with sensors and to verify data by sending it to the management server using portable data storage devices, wired and wireless communication devices. This method requires AC power for data logger and communication device to process data measured at multiple stations because data logger, communication device, and management server are composed of one unit. As a result, the volume of the data processing unit increased and the need for power cables and management servers resulted in many initial costs, making it economical.

In this research, first, the system configuration was simplified by integrating data logger functions and communication functions, and secondly, it plans to develop near-field wireless remote devices that are free of charge and remote wireless remote devices that are paid for communication. Therefore, constructability was secured by simplifying system composition, and economic feasibility could be achieved by reasonably deploying near- and long-distance wireless remote devices.

2.7 How to Build Near-Field and Long-Range Wireless Remote Measuring Devices

First, this research constructs an NFC remote measuring device where the location of measurement locations in the field is relatively close (within 80 m) and communication costs are free. Second, it is a method of receiving data from a near-field network from a remote wireless integrator and transferring it to a web server, making it possible to build an economical system that does not require cable laying.

- When configuring a NFC remote measuring device: If the distance between the measurement locations is relatively close-range, only one remote device will be installed and the rest will be composed of NFC remote measuring devices. Consequently, communication costs are saved.
- When configuring a remote wireless network: If the close-range network cannot be configured due to the distance between the measurement locations, install a remote wireless remote device at each measurement location. Constructability is improved because there is no need for separate cable laying.
- Wireless Remote Measuring Device Main Functions: Bi-directional communication (multi-connect multiple devices). Wireless communication method selection functions (RF and WCDMA selection and mix)

2.8 Development of a Safety Management Monitoring Program

Fig. 9 shows the conceptual diagram of safety management monitoring, which is managed by storing instrumentation data transmitted from wireless remote devices (RTU) in a database of remote server systems. In addition, stored instrumentation data can be viewed and managed through remote management programs wherever the Internet is connected and SMS text information will be automatically delivered in the event of an alarm.

Fig. 9 illustrates the conceptual diagram of program development and summaries the following: First, the program consists of a wireless remote measuring device and a client program capable of collecting instrumentation data, sending control commands, and controlling devices for DB and server management. Second, the main functions of the server program include storing measurement data in databases, setting up databases and field records, setting up Internet IP for communication, monitoring communication device status, controlling communication devices, and database management. Finally, the main functions of the client program are the measurement data inquiry and output function. It has measurement data analysis and output functions, safety and usability assessment functions, and alarm management functions.

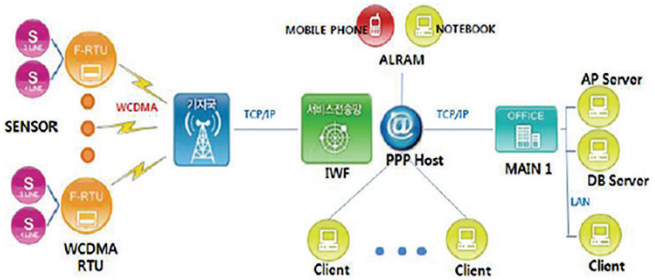

Figure 9 Conceptual map of safety management monitoring

If research result on the wireless remote safety measurement device for a multi-waterproof sensor-based structure is applied to the field, it can proceed with the platform process as shown in Fig. 10. Through these research results, it is possible to provide data necessary for preliminary safety diagnosis and damage recovery of structures through continuous management of facility safety maintenance.

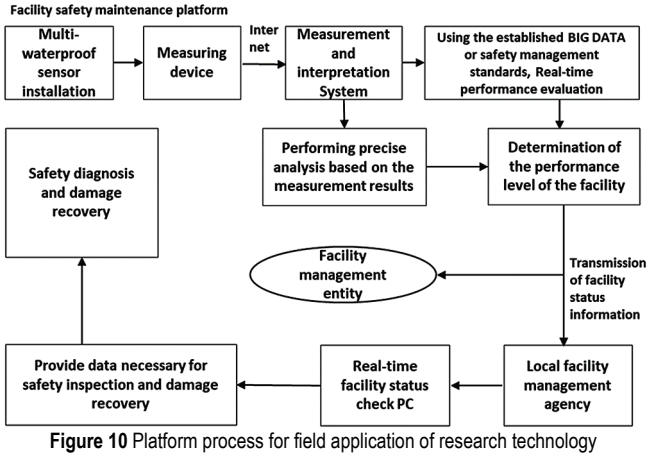

Figure 10 Platform process for field application of research technology

3 CONCLUSIONS

Recently, the construction industry is paying attention to permanent safety management of major national facilities. Research and development of facility safety management based on a real-time safety monitoring system can prevent large-scale accidents of structures in advance. Real-time data can be collected through short- and long-distance

communication by connecting wireless-RTUs through research on wireless remote safety measurement devices based on multi-waterproof sensors. In addition, the stability of the structure can be managed in real time during or after construction by researching a management and analysis program that can be shared with field managers and rescue experts in a web environment by data base the collected data. The main research results are as follows.

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As structural stability can be determined and control signals can be calculated quickly, risk management of structures can be effectively performed, safety accidents can be minimized. Using a wireless telemetry device (RTU), the system is simplified and easy to operate and manage. By developing multiple waterproof sensors, waterproof performance is excellent even in places where water is used. Since technicians can detect it in real time without waiting at all times, it is expected to reduce the risk of disasters or casualties that may occur in the event of an abnormality as much as possible, and further use it in shipbuilding and other fields.

It is necessary to add various sensors that can monitor the condition of various structures in the future and develop them into intelligent systems such as life cycle prediction of structures, and expand the development and distribution of wireless network-based systems.

As a limitation of this study, it is necessary to verify the economic efficiency through field applicability evaluation to the existing research system. In future research, quantitative analysis should be analyzed through application data of actual projects.

Acknowledgment

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Notice

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Author's contacts:

Chang Jin Yang
Department of Architectural & Civil Engineering,
Dong-Seo University,
47 Jurye-ro, Sasang-gu, Busan 47011, Korea
cjyang@dongseo.ac.kr

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Structure Earthquake Analysis Program using Computer-Aided IT Sensor

Dong Oun Lee

Abstract: The purpose of this study is to develop a complex test and analysis technique to improve the reliability of seismic performance evaluation of buildings, and to establish a seismic performance evaluation system using shear damper as an earthquake preparation technology. In this study, validated examples of viscoelasticity provided by OpenSees were selected for verification of hybrid experimental results data and compared with hybrid experimental techniques. By applying the analysis program and the developed Labplugin, the hybrid experimental system built through the connection between the equipment was verified. As a result, the behavior of the cyclic loading test showed the general behavior of the damper, but in the hybrid test, the behavior of the damper with respect to the ground acceleration and the decrease in stiffness caused by fracture were found. From the above comparison experiment, it can be seen that the hybrid technique developed in this study shows excellent seismic behavior compared to the cyclic loading experiment, dynamic experiment, and analytical technique. With the system built in this study, it is judged that it is possible to design a structure damper in the future. In addition hybrid experimental system will help to conduct more economical and reliable research on seismic control by applying partial experimental data to structures with nonlinear behavior in the future.

Keywords: analysis program; IT sensors; hybrid experiment system; seismic analysis; steel damper

1 INTRODUCTION

In recent years, there have been earthquakes in the Nepal earthquake in 2015, and even in Korea, earthquakes such as Gyeong-ju Earthquake (2016) and Pohang Earthquake (2017), which occurred within the Korean Peninsula's influence zone, have been reported in Korea. It also proves that it is not an earthquake safe zone. There are still earthquakes in many places, but there is still a shortage of response technologies. The hybrid experimental analysis system was applied as an experiment and analysis system that more accurately reflects the behavior of dampers caused by earthquakes [1].

Hybrid experimental technique development has been actively carried out since the early 2000s, and in the United States and Canada, through hybrid experiments, the advantages of each laboratory device are linked with the program, and experiments and interpretations are carried out at the same time, making more precise experiments[2]. In this study, the algorithm for seismic characteristics analysis through hybrid experiments, and the shear pulsation damper applied with the actual hydraulic actuator through Labplugin developed to apply the actual damper values. In addition, the seismic characteristics were analyzed by the hybrid test on the building with shear damper. The hybrid analysis program used UI-SIMCOR2) developed by NEES, and the validity of the data results of the hybrid system was verified by comparing them with the OpenSees analysis results.

In addition, the building to which the shear-type steel damper was applied was modeled according to the hybrid experiment and the behavior was analyzed to evaluate the verification of the system construction and the validity of the results [3]. Tab. 1 summarizes the advantages and disadvantages of hybrid experiments for quasi-static experiments and vibrating table experiments, which are the existing experimental methods.

The purpose of this study is to construct a hybrid experimental system for reliable analysis by analyzing the overall behavior of the building through the interlocking of the experimental data of the damper and the analysis data of the building. The goal of this experimental technique is to design and develop a damper in the future, and to establish a seismic analysis process for a complex analysis structure to which the damper is applied.

Table 1 Advantages and disadvantages of experimental techniques

Division	Quasi-static experiment	Hybrid experiment. (Similar experiment)	Vibration test.
Experiment method	Experiment and analysis of the previously analyzed displacement history in the absence.	Experiments and analysis in which the step is numerically analyzed in every step of the hour to emphasize displacement, and then the response is exchanged and calculated in real time	Experiment and analysis through the behavior of the diaphragm similar to the actual ground motion
Strengths	Simple structure The cost of the experiment is low	It can mimic the destructive behavior relatively accurately. There's little limit on the size of the test subject. Small improvements make deployment less expensive	Responses, collapse procedures, and residual deformation of structures close to reality can be identified.
Weakness	Dynamic stiffness change cannot be considered	Since the experiment is conducted by dividing the time into stages, the dynamic effect of the actual earthquake history cannot be considered because there is no concept of time	The deployment cost is high. Limit of capacity. Error due to reduction

Therefore this study is to construct a hybrid experimental technique system that simultaneously conducts experiments and analyzes by connecting the experimental values of the steel dampers with the whole building analysis to analyze the damper-installed buildings.

2 METHODOLOGY

2.1 Substructure Analysis

In the partial structure quasi-dynamic seismic response test, the members or households that are considered to have a great influence on the response properties, especially in the structure under review, are replaced by mathematical models. It is one of the experimental techniques to simulate the earthquake response of the whole structure by performing numerical analysis [4].

2.2 Hybrid Test

As shown in Fig. 1, hybrid test is an experimental method that introduces partial structure technique to Pseudo-Dynamic Test in order to evaluate the seismic behavior of structures efficiently and more realistically. Simultaneously analyze the earthquake response of the structure as a local partial test of the structural element or substructure in parallel with the loading test and analysis.

Simultaneously analyze the earthquake response of the structure as a local partial test of the structural element or substructure in parallel with the loading test and analysis. The advantages of the hybrid experimental technique are that it avoids the problem of scale, which requires the specimen of the shaking table to fit the size of the shaking table, can reasonably handle the seismic response of the structure as well as the scaled specimen, and can observe the destruction process in detail [5].

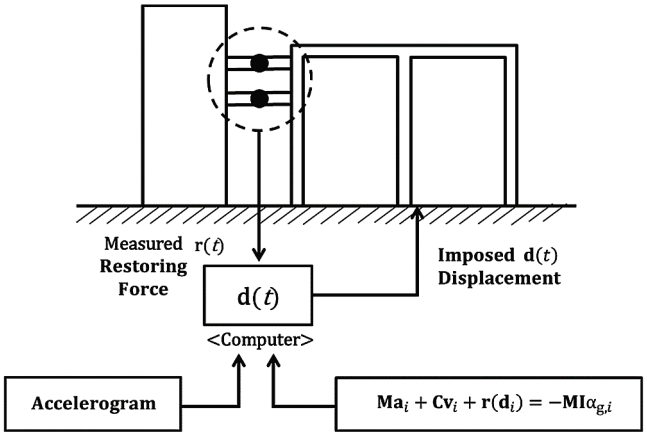


Figure 1 The pseudo-dynamic testing method

And many structural analysis programs developed in recent years have their own advantages. If you can take advantage of the inherent analysis capabilities of these various analysis programs, you can create more realistic structural analysis models for more complex structures. After dividing the target structure into analysis modules and experimental modules, the results obtained through experiments or analysis of each module are fed back at every hour increments, and then the behavior of the whole structure is obtained through dynamic motion equations [6].

2.3 Shear Type Damper

Shear type damper is a shear yield type vibration damping device that can be installed in the center of connecting beam where the bending moment is hardly generated in the connecting beam and the maximum shear deformation occurs and can increase the damping efficiency of horizontal load [7]. By installing one energy dissipation device in the center of the beam, it is possible to dissipate more energy in the beam that takes much shear force.

Fig. 2 shows the installation position of the sheared pulverized beam. The beam is subjected to the bending moment and shear force according to the relative displacement of the shear wall, and it is possible to minimize the damage of the existing structure by dissipating energy by applying the damper, an energy dissipation device, by using the deformation of the shear wall and the cross-sectional force generated in the shear beam. Fig. 3 is a diagram explaining the shear force of a pulley beam on the behavior of buildings during an earthquake [7].

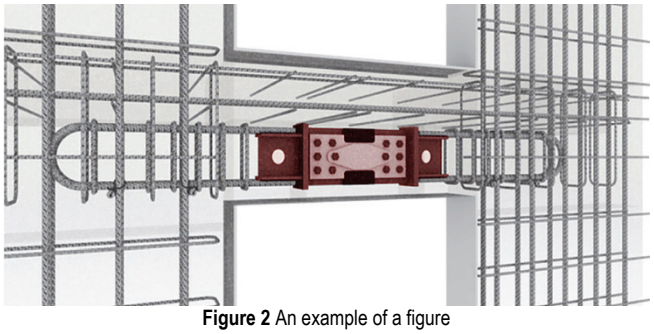


Figure 2 An example of a figure

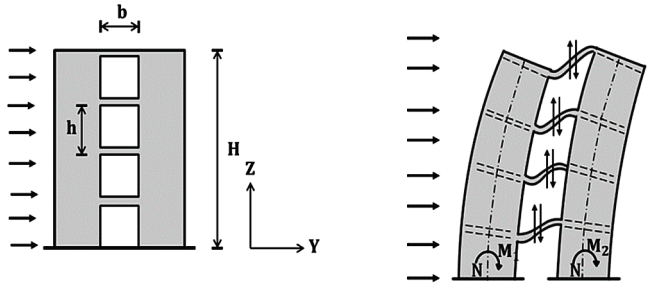


Figure 3 The principle of relative deformation of the shear wall under lateral force

3 HYBRID EXPERIMENTAL CONFIGURATION

3.1 Experiment Algorithm

The purpose of the hybrid experiment is to perform the complex analysis of the structure where the damper is installed because the experimental data of the damper is analyzed in conjunction with the analysis data of the structure in order to increase the reliability of the structure analysis in the seismic performance evaluation [8].

3.2 Composition of Ui-SIMCOR

UI-SIMCOR can distribute and control pseudo-dynamic analysis in several sites, and the number of control is not limited. With a variety of communication protocols, you can

test from a single degree of freedom system to highly complex structures. Simulation can be any experiment, any combination of experiment and analysis, any analysis, and UI-SIMCOR applies a static force that is not time-dependent. Figure 4 is a program form of UI-SIMCOR, and figure 5 shows the execution order and description of the UI-SIMCOR.

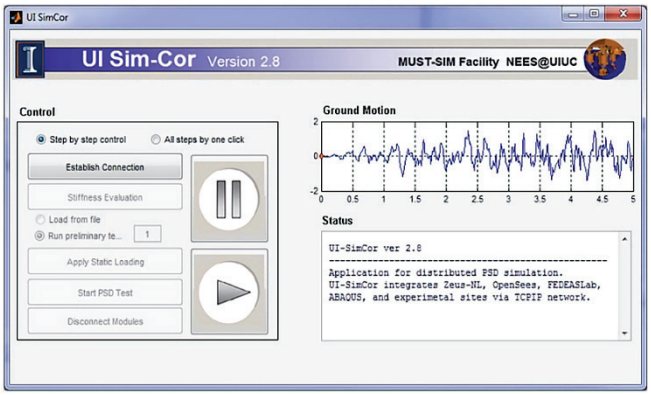


Figure 4 UI-SIMCOR

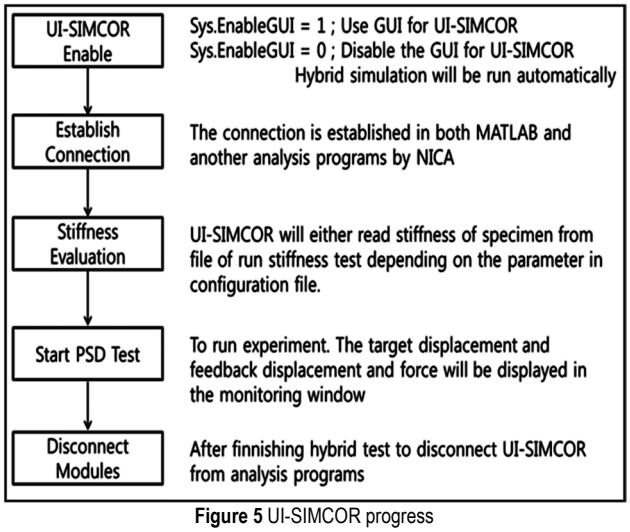


Figure 5 UI-SIMCOR progress

In this hybrid experiment, in order to see the dynamic force exerted on the structure in more detail by integrating the seismic acceleration, the velocity and displacement are made by integrating the seismic acceleration, and the displacement value is divided into 500 steps. When one displacement is applied, one restoring force is measured by static analysis and the pseudo-dynamic analysis is performed. Construct the building to be analyzed as a model using the finite element method, divide the building model into parts by applying the partial structural analysis method, and build the individual analysis program or the test object and collect the results of the experiment and analysis again in Matlab to analyze the results of the entire model.

In this experiment, the actual actuator displacement value transmitted through Labplugin is transmitted to the third substructure of MDL3, and the damper's experimental result is transmitted as an analysis value through LabPlugin. Since we proceed to displacement control, we move the actuator by sending displacement of MDL3 node to Labplugin. After that, due to the displacement of the actuator, the restoring force value is extracted from the load cell connected to the shear damper, and then returned to the program analysis [9].

4 LABPLUGIN

In the hybrid experiment, the displacement of each node is transmitted to the modular substructure in UI-SIMCOR, and the reaction force is measured by the analysis program or the experiment and put into the overall structure matrix for analysis. At this time, the experimental data can be transmitted only to the program with communication system such as TCPIP. So, if there is no communication system in the program that handles devices, Labplugin should be developed and connected. When performing the hybrid experiment, Labplugin receives the displacement data from UI-SIMCOR through TCP / IP, moves the actuator by the corresponding displacement, measures the displacement and load value of the actuator, and transmits it to UI-SIMCOR to interpret the experimental data.

The part setting for the instrument reading the load cell and displacement meter, the manual operation part, the graph indicating the target displacement of the actuator including the hybrid, the position graph of the actuator, and the reaction force graph that adjusted the measurement result value, UI-Consists of displacement and reaction force graph when transmitting to SIMCOR. In addition, the displacement shape transformation coefficient applied in the non-x direction makes it possible to analyze brace-like structures. As a limitation, it is not currently available if it is not in one direction, and there is an error due to time difference between analysis and experiment [10].

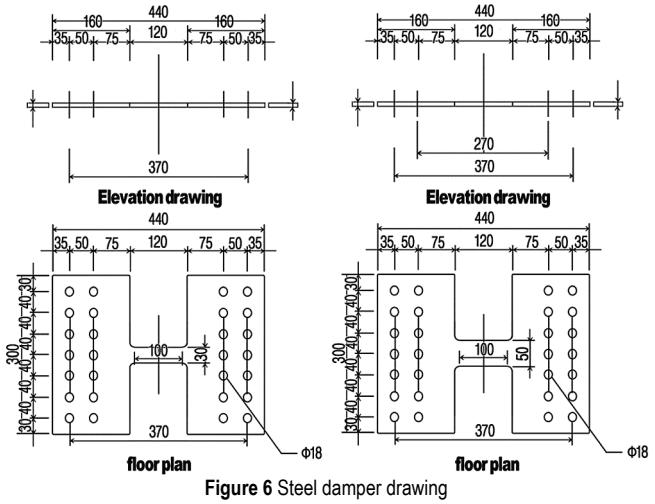


Figure 6 Steel damper drawing

4.1 Specimen

Tab. 2 defines test steel dampers applied to this study. For steel dampers with 30 × 5 mm shear area, 30 steel dampers are designated as symbols and 50 steel dampers for 50 × 5 mm shear area.

Table 2 Specimen number

No	Specimen	Design Variables
1	30 Steel Damper	Shear area 30 × 5 mm
2	50 Steel Damper	Shear area 50 × 5 mm

Fig. 6 is a drawing of test damper steel damper. Fig. 7 is a picture of the steel damper set up.

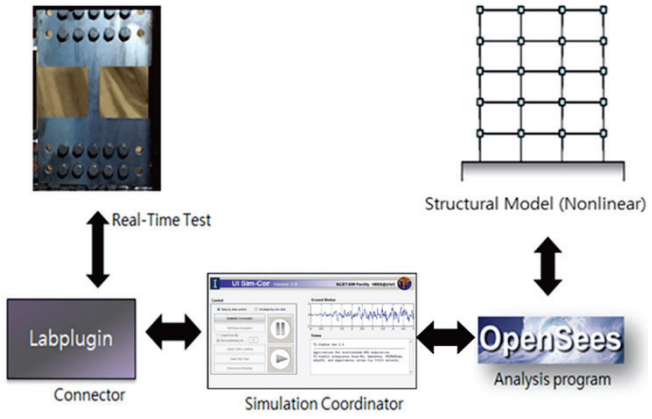


Figure 7 Hybrid experimental diagram

5 EXPERIMENT CONFIGURATION

In order to verify the hybrid experimental technique, the frequency design test, the fault structure analysis, and the terminal induction test were carried out. These are summarized in Tab. 3. Example Structure 2 of Multi-Stie Online Simulation Test (MOST) is a sample structure provided by UI-SIMCOR, the main program of hybrid experiments made by NEES, and the result data is verified by comparing with other programs.

Table 3 Experiment plan

Test Name	Specimen Type	Analysis
MOST (2Bay 1Story) Structure Hybrid Experiment	None	OpenSees
	30 Steel Damper	Hybrid Test
	50 Steel Damper	50 Steel Damper

5.1 Experiment Setup

This experiment is to evaluate the seismic performance of the actual shear type damper using the actuator. The 100t hydraulic actuator was used and the test damper was installed. Figs. 8 and 9 is the experimental setup. In order to transmit only the shear force, four longitudinal H-beams were installed and horizontal bars were placed in the middle to install horizontal bars. And to prevent eccentricity, rollers and rails were installed to move only on the *x*-axis. The results of the experiment were applied to the hybrid system, and the experiment was carried out by constructing the experiment analysis through interworking between programs. The measurement was performed using an Agilent 34972A meter. Fig. 10 and Fig. 11 are actual setup photos and damper installation photos.

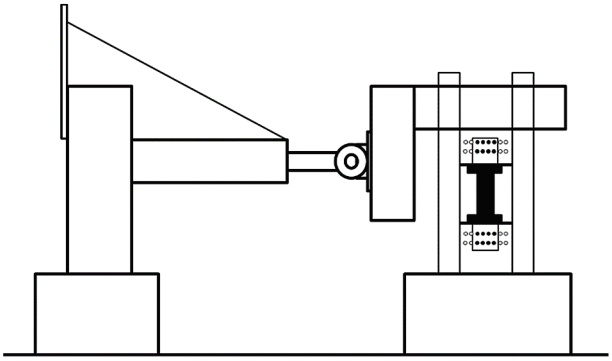


Figure 8 Experiment setup no. 1

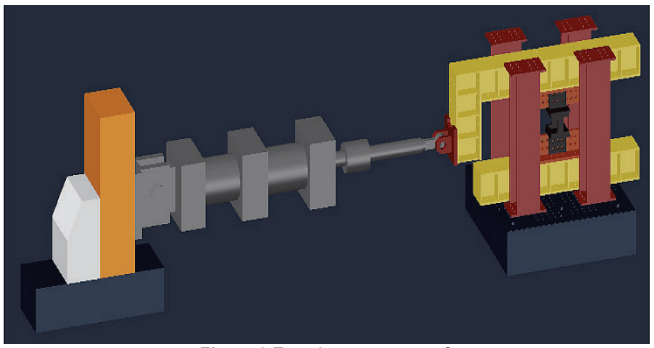


Figure 9 Experiment setup no. 2

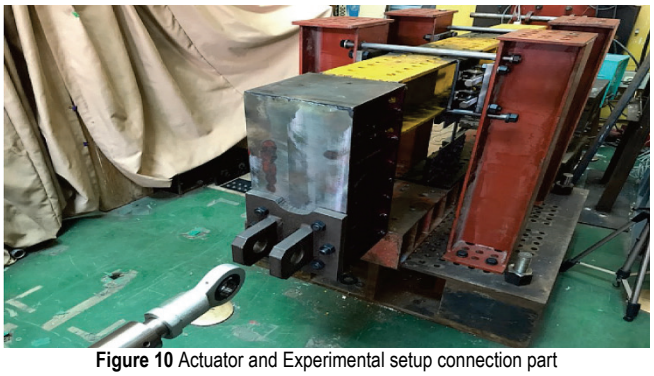


Figure 10 Actuator and Experimental setup connection part

Figure 11 Steel damper setup

5.2 Hybrid Test System

The hybrid experiment is constructed by applying the finite element method to the building to be analyzed, and by applying the partial structural analysis method, the building model is appropriately divided, the individual analysis

program or the test object is constructed, and the results of the experiment and analysis are gathered back to the UI-SIMCOR.

6 STRUCTURE HYBRID TEST EXAMPLE

6.1 Example Model

The Multi-Stie Online Simulation Test (MOST) example structure is an example structure provided by UI-SIMCOR, the main program of the hybrid experiment made by NEES, and the result data is verified by comparing with other programs. Fig. 12 shows the application of steel dampers to modeling. Fig. 13 is a modeling diagram for hybrid experiments. When shear dampers are installed in the central column of MOST structure, the behavior of damper is analyzed and the effect on the whole structure is analyzed.

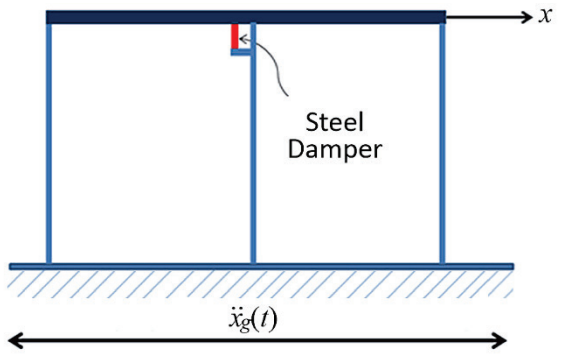


Figure 12 MOST structure with shear damper

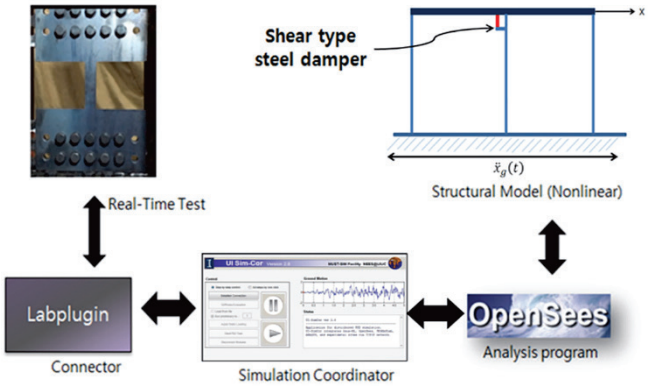


Figure 13 Hybrid experimental diagram

6.2 Acceleration Graph

The structure consisted of 3 parts and analyzed. The seismic wave was Acc475C seismic wave. Fig. 14 is a graph for Acc475C, the ground acceleration applied to the analysis.

6.3 Experiment Result

Fig. 15 shows the force displacement of the structure with ground acceleration, and Fig. 16 shows the force-displacement graph for the nodes.

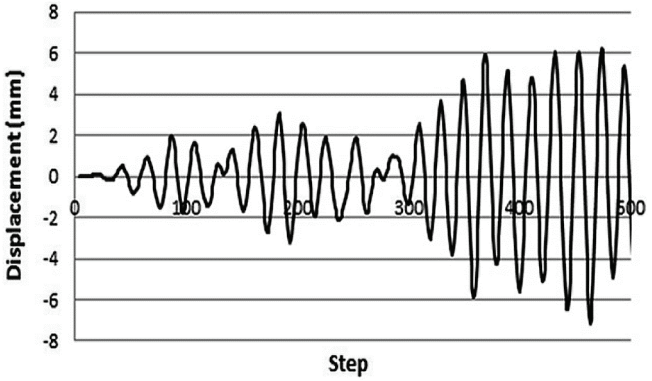


Figure 14 Acc475C acceleration graph

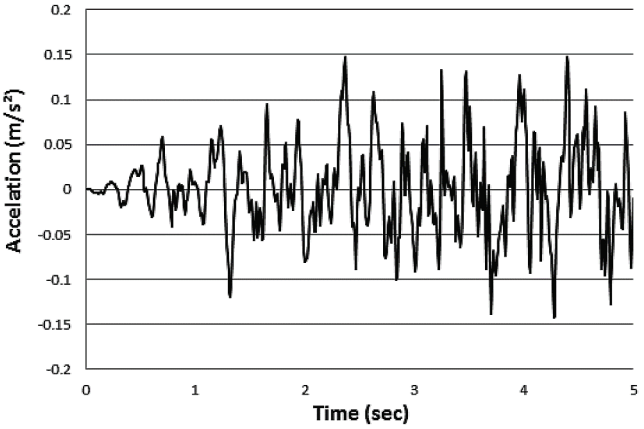
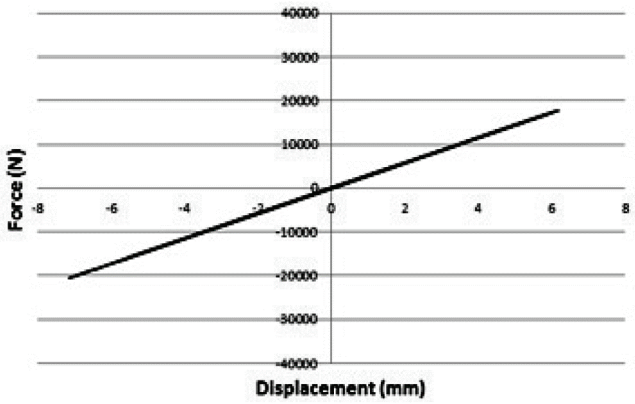


Figure 15 Applied displacement

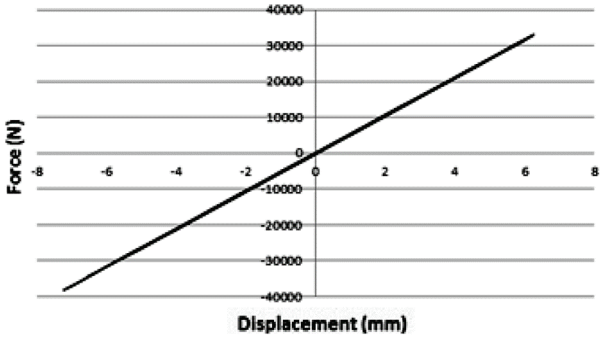
In Fig. 15, 500 quasi-dynamic analyzes at 0.01 second intervals showed that the displacement of the structure moved 6mm and –7 mm at the origin, so the maximum width of 13 mm had the greatest effect on the structure. For this displacement, the structure is shown in Fig. 16. This is a force-displacement graph for the left, center, and right columns of the MOST structure, respectively. The graph shows a linear graph of 30000 N (3 Tons) for 6 mm. The reason why the linear graph appears is that the yield point of the modeled structure has not been reached.

Fig. 17 shows the force displacement of a damper-mounted structure and Fig. 18 shows the force-displacement graph for a node.

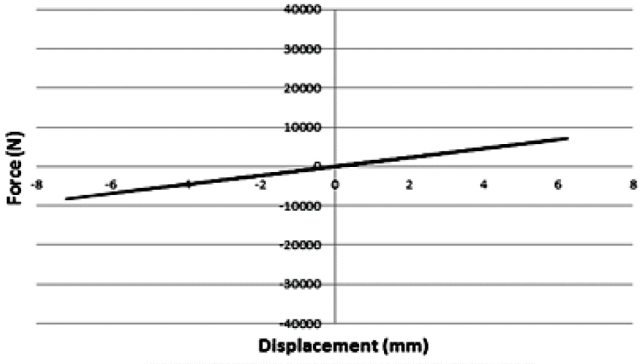
In the model where the shear type steel damper is installed on the two-node central column by applying the hybrid system, the displacement is similar to the displacement applied in the OpenSees analysis. At the nodes for each column, however, the force-displacement graph changed slightly under the influence of the damper, unlike the linear graph in the OpenSees analysis. Fig. 19 shows the force-displacement graph of the damper experimental data when the structure is analyzed by the quasi-dynamic analysis.



(a) Left column Force-Displacement Graph



(b) Middle column Force-Displacement Graph



(c) Right column Force-Displacement Graph

Figure 16 Force-displacement graph of the MOST example

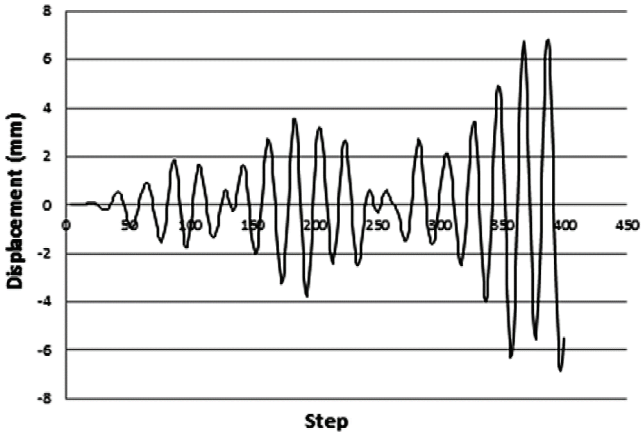
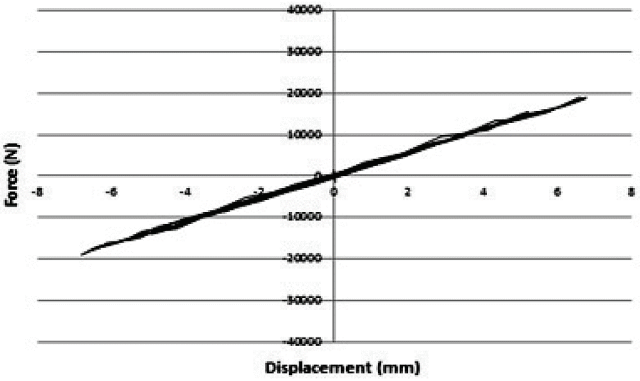
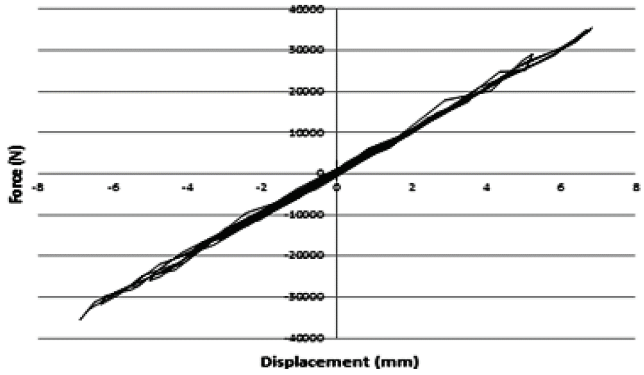


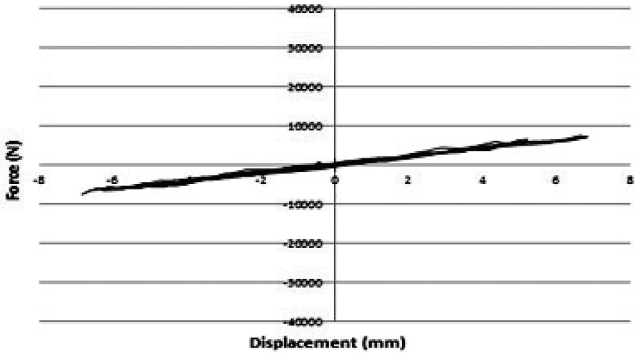
Figure 17 Applied displacement



(a) Left column Force-Displacement Graph



(b) Middle column Force-Displacement Graph



(c) Right column Force-Displacement Graph

Figure 18 Displacement graph of MOST hybrid test

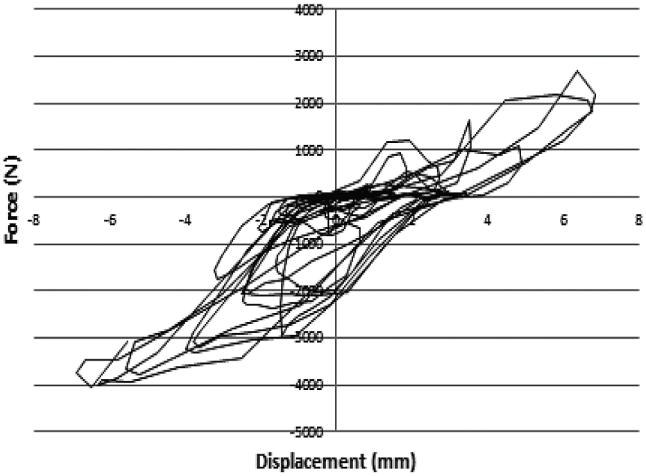


Figure 19 Force-displacement graph of 50 steel damper

7 CONCLUSIONS

In this study, a hybrid test system was constructed to analyze the complex structure due to the application of dampers. Hybrid test system is an experimental technique that analyzes the whole structure by dividing the whole structure into substructures, combining the experimental results of the damper with the analysis results of other parts through the analysis program. The structure of the damper against the earthquake of nonlinear structure controlled by shear type damper was analyzed by testing the structure of steel damper which is the test body of shear type breaker damper. In future research, it is necessary to reduce the errors caused by time difference, instrument error, and understanding of the model due to systemic errors.

In this study, the structural analysis was performed by applying the steel damper, which was made arbitrarily for the purpose of building a hybrid test system. In addition, it is expected that the constructed hybrid test system will be more economical and reliable for the study of seismic control applying partial experimental data on nonlinear behavior structures in the future. In addition, hybrid experimental system will help to conduct more economical and reliable research on seismic control by applying partial experimental data to structures with nonlinear behavior in the future.

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Notice

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Author's contacts:

Dong Oun Lee
Department of Architectural & Civil Engineering,
Dong-Seo University,
47 Jurye-ro, Sasang-gu, Busan 47011, Korea
ldu21@hanmail.net

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An Approach to the Application of the Internet of Things in Logistics

Dominika Crnjac Milić*, Irena Dujmenović, Marina Peko

Abstract: The Internet of Things (IoT) is a technology of the future that is being widely applied in business environment. Companies around the world are starting to apply IoT technologies to ensure the most efficient business possible. The importance of the application of this technology has been particularly evident in improving logistics processes. This paper describes IoT applications in processes such as supply chain management, i.e. control of transport and storage of goods and materials. Examples of smart solutions offered by IoT technology are presented. Various technologies and standards are used in the implementation of the IoT. The scientific community is increasingly researching new technologies such as NB-IoT and 5G, which provide an even greater potential for IoT development. Therefore, this paper shows a comparison of these technologies and explains how IoT devices work with them.

Keywords: 5G network; Internet of Things (IoT); logistics processes; Narrowband Internet of Things (NB-IoT)

1 INTRODUCTION

The Internet of Things (IoT) is one of the most advanced technologies nowadays that is applied in almost every aspect of our lives. The IoT connects smart devices and enables them to communicate with each other and with the environment. A network consisting of such connected devices collects and exchanges data, which is later used to perform necessary actions. The IoT plays an important role in business environment, especially in logistics. According to [1], logistics as an activity is responsible for monitoring distribution networks and managing the flow of resources and final products. According to [2], logistics mission is "to get the right goods or services to the right place, at the right time, and in the desired condition, while making the greatest contribution to the firm". Logistics strives to integrate the handling of materials and information, the provision of services to consumers, logistics communications, the monitoring of warehouse locations and transport tracking. Control of the two main logistics actions, transport and warehousing, can be significantly improved through the use of IoT technology. Collecting information using sensors provides insight into important data which will be used for further work. The Internet of Things offers the opportunity to connect logistics infrastructure by all parts of the supply chain, creating a functional unit. Connecting resources, goods and devices greatly helps to create a unique environment with automated functions. The IoT ensures traceability of information and goods. Transport control, supply and shipment tracking, optimization of vehicle routes, automated maintenance of infrastructure elements are some of the applications of IoT technology in logistics. According to [3], doing business optimally means finding solutions that will provide the lowest possible costs. Acquisition, implementation and maintenance of modern and sophisticated technologies such as the IoT imply significant costs for the company, but since it provides tracking of all resources of a company, it ultimately plays a significant role in achieving savings.

According to [4-6], transport control includes determining the location of transport vehicles and tracking them on routes. Important parameters that need to be monitored are vehicle temperature, vehicle humidity, lighting conditions and the like. The goal is to get optimized vehicle routes, reduce fuel consumption, effectively and efficiently maintain the quality of transported resources, and speed up loading, reloading, and unloading. The IoT provides automation of processes and ensures a quick response to possible irregularities, since it ensures real-time monitoring of data. In addition to transport, it is important for companies to control the flow of materials and information in warehouses. The functionality of the warehouse is reflected in its management. According to [7], modern warehouse management systems require automatic identification and monitoring of data and warehouse activities in real-time. Identification of forklifts, pallets and warehouse employees is important for successful organization of all warehouse processes and their management. With the help of IoT technology, it is possible to control all warehouse parts and monitor and analyze data important for further processes.

The paper consists of three sections. The introduction is followed by a more detailed discussion of the importance of applying the IoT in transport logistics and warehouse logistics. Section 3 presents a comparison of the technologies, while Section 4 points to the future of the application of technology in logistics, the 5G network, and the challenges that the application of technology brings. This is followed by a conclusion on the lessons learned in the paper and recommendations for further research. The methods used in the paper are analysis, synthesis, induction, and deduction of knowledge and facts from available primary, secondary, and tertiary sources in which scientists and experts have presented their prior knowledge relevant to the topic of this paper.

2 DISCUSSION

The following section describes IoT technologies used in transport and storage activities. IoT solutions are realized by integrating different hardware and software. These are various wireless and network sensors, microcontrollers, microprocessors, and systems such as GMS (Global System

for Mobile Communication), GPS (Global Positioning System), GPRS (General Packet Radio Service), RFID (Radio-Frequency Identification), cloud technologies, and Wi-Fi. Tracking and managing cargo in the transportation and logistics industry requires a solution that is fully mobile and can travel with cargo while staying connected and communicating back to the home servers/platform. For connectivity on a global scale, regardless of where your device moves, one of the best recognized solutions - particularly for large-scale deployments - is cellular M2M connectivity (Mobile to Mobile).

Table 1 Application of IoT technologies in transport

Product/application	Company	Technology used	Results
SmartPORT: measuring activities in and around the river port, monitoring parameters such as temperature, humidity, wind direction, air pollution, water level, goods flow management, networked ships, bridges and other port elements	SAP in cooperation with Deutsche Telekom and the ADAC car club (Germany)	Cloud technology, mobile applications for real-time communication	Increased port permeability, connected participants in traffic and logistics, reduced CO_2, smart lighting, better driver awareness in the port, reduced waiting, improved routes, digitalization of port traffic inspections [16]
Real-time monitoring and controlling of transport distribution centres	MOST (Sweden)	GSM network, sensors, cloud technology	Improved transport actions, route optimization, better shipment control [17]
Transport and equipping with the regulation of temperature, humidity, brightness and shipment pressure, sending warnings in case of irregularities, vehicle tracking and connection to the central station, providing insight into the condition of the roads	DHL (Germany)	Sensors, GPS	Improved transport services, route optimization, better information of the traffic condition, timely warnings of obstacles [17]
TruckCam: simultaneous video and audio recording in the vehicle cabin and recording of the route	TruckCam AB (Sweden)	Cloud technology	Accident investigation during transport, safety improvement [18]
GSETrack: monitoring and tracking of luggage carts and other non-motorized equipment at the airport, sending and receiving equipment information	Undagrid (Netherlands)	LoRa, BLE	Facilitated location of equipment, more efficient transfer of goods [19]

Table 2 Application of IoT technologies in warehousing

Product/application	Company	Technology used	Results
SmartLift: tracking the location of goods in the warehouse in real-time and the speed and direction of the forklift	Swisslog (Switzerland)	Big Data, sensors, GPS	Reduced storage costs, higher productivity and efficiency and increased security of supplies and employees [16]
Smart systems installation in the energy consumption of the warehouse, sensors placed in the infrastructure of the warehouse monitor and regulate the lighting ventilation and heating level	OHL (SAD)	Sensors, cloud technology	The analysis of the collected data enables control of energy consumption, reduction of costs [16]
Supply chain monitoring, temperature, chain compliance and visibility tracking, refrigerated containers monitoring	GlobeTracker (Denmark)	Wireless sensors, Bluetooth, LoRa	The company has insight into events inside the warehouse, increased income, increased efficiency [17]
VoiceXtreme: real-time voice warehouse management	Spica (Croatia)	Wi-Fi, sensors	Improved work efficiency, speech communication leaves more room for manual handling and other tasks, easier management of industrial facilities [20]

2.1 IoT in Transport

According to [8], controlling transport means managing fleets, monitoring the vehicles used by the company, and the activities of the company's employees. The IoT finds application here in vehicle cloud monitoring. The technology needs to be built into the vehicles, and monitoring is done through any device connected to the Internet, such as a cell phone. GPS is used to determine the location of vehicles and track routes. The connection to the Internet application is established via GPRS. In fact, a GPS signal, which uses the GNSS network (Global Navigation Satellite System), provides information about the current location, direction of movement, time and speed of the tracked vehicle. Among other information collected through IoT devices, all collected data is subsequently stored in the cloud, allowing users to get reports on trips and travel expenses, cargo status and the like. The IoT also enables the execution of functions such as creating travel orders and provides control of the vehicle while driving whenever it is connected to the Internet. According to [9], in logistics, it is crucial to get information in a timely manner. That means the company can monitor its vehicles at any time. Real-time tracking brings improvements for transport by reducing delays or, for example, simply solving problems in determining the most convenient routes. In addition, when transport problems arise, a response and finding a solution by means of the IoT can be much faster than before. According to [10], it is important to monitor the condition of products during transport and RFID technology can be used for that purpose. The built-in sensors with RFID collect product data, which allows control over them. In addition, it is important to collect information about vehicle maintenance and monitor driving conditions. According to [11], this is done with the help of OBD technology (On-

Board Diagnostics). All information stored in the cloud can then be analyzed and feedback can be sent to the driver's cell phone as needed. Drivers receive instructions via special IoT applications. This way of connecting devices and using these technologies helps the effective development of the company. With the IoT, as stated in [12], transport becomes automated, and its application provides better opportunities for the development of logistics of any company.

2.2 IoT in Warehousing

According to [13], traditional systems require more employees in warehouses. Today, efforts are being made to build smart warehouses that will utilize human resources exclusively to control the processes carried out in the warehouse. Based on [14], the IoT provides automated processes and networking of physical components facilitating warehouse management. Supply classification, tracking orders, monitoring the shelf life of products and parameters such as temperature, air humidity, and other conditions in the warehouse are important for its efficient functioning. According to [15], it is important to control shipping and replenishment of goods. In this way, goods can reach the right users at the right time. Supply control and availability of information about the location or quantity of goods can be realized using RFID technology. According to [16], the IoT can offer numerous benefits to warehouses such as precise control of goods and real-time management, timely detection of problems and irregularities, visibility of all processes, employees, and supplies, increased efficiency and employee safety, and monitoring the condition of goods and warehouse conditions. The information needed to control all these processes is collected using built-in sensors. By analyzing the collected data, problems in the warehouses are solved in time and an optimal response is provided. In addition to supply control, it is important to pay attention to the maintenance of equipment in the warehouse. With the help of the IoT, it is possible to monitor data on damage or defects and reduce human error, which in turn reduces the costs of the company. The sensors monitors the conditions in the warehouse and signals significant changes to the WMS (Warehouse Management System) with the appropriate software. By installing cameras on forklifts, it is possible to scan the space and thus reduce the risk of accidents, which increases employee safety. Sensors can detect the condition of pallets to better ensure proper handling. When a problem occurs, employees are notified thereof through a specific application and cane then manage warehouse processes with increased safety. Warehouse conditions are not always ideal, so it is important to monitor the health of employees. The IoT finds application here as well, for example, with devices such as smartwatches or smart wristbands. They measure heart rate or calories burnt, and timely notification of physical changes can prevent potential injuries and problems.

Tabs. 1 and 2 show different products of individual global companies and describe their application related to transport and storage. The technologies used in their implementation and the results achieved through the application of the IoT are listed.

3 TECHNOLOGY COMPARISON

Connectivity is a critical component of the Internet of Things. IoT devices rely on networks to communicate with gateways, applications, servers, routers, and other IoT devices. This communication - data transmission and reception - enables IoT devices to perform the functions they were designed for.

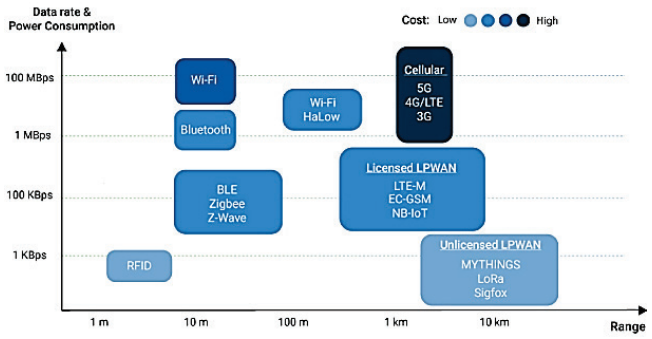

Figure 1 Comparison of IoT technologies by certain characteristics [21]

The IoT uses various protocols and technologies that enable its implementation. Different companies have different needs in relation to the IoT, and the type of technology applied depends on these needs. It is important to think about the spectrum to be used (licensed or unlicensed), the data rate required, power consumption, the number of devices that must be connected, and how much all that costs. Fig. 1 shows the relationship of different technologies by their reach, data rate, energy consumption and costs, and these are described in more detail below.

According to [22, 23, 24], one of the unlicensed networks is SigFox and it is the first global IoT network. It operates within the frequency band ranging from 915 MHz to 928 MHz (USA), at 868MHz (Europe) and at 433 MHz (Asia). It is characterized by low implementation costs and low noise levels, hence low energy consumption. It uses many devices that communicate with each other. The data rate is up to 100 bit/s. Based on [24], another unlicensed network is LoRa, which operates in the frequency band ranging between 868 MHz and 915 MHz. It enables secure data transfer with low power consumption. It covers up to 8 km in urban areas and up to 22 km in rural areas. The baud rate can be adjusted from 0.3 to 50 kbit/s. It has high noise resistance and uses SS (Spread Spectrum) and CSS (Chirp Spread Spectrum).

A wireless local area network (WLAN) is a network that provides high-speed internet and secure communication. It is also known as Wi-Fi. It is based on the IEEE 802.11 standard and used to transmit sensor data within a range of 100 m. The data rate ranges from 2 Mbit/s to 600 Mbit/s. Unfortunately, the implementation of WLAN can be very expensive for large smart grids.

According to [24], ZigBee, a low-power broadband network, is also in the unlicensed spectrum. Its implementation is simple and cheap, but it has low coverage of up to 100 m. It is based on the IEEE 802.15.4 standard. Data rates are up to 250 kbit/s in the 2.4 GHz band, 40kbit/s for 915 MHz, and 20kbit/s for 868 MHz. ZigBee technology

is prone to interference and does not have large processing capabilities.

According to [24], WiMAX wireless technology is based on the IEEE 802.16 standard and it uses a 4G network. The data rate is up to 75Mbit/s, and the coverage is up to 50 km. It has a short delay of 10 to 50 ms. Its implementation is expensive, thus just like SigFox, it is not ideal for larger smart grids. Broadband low-power networks (LPWAN) are suitable for the IoT. As a result, standards have recently been considered that will enable more successful implementation of the IoT. Examples include the licensed standards NB-IoT and LTE-M. These are technologies that incline towards the 5G network, which holds the key to future communications.

According to [25, 26, 27, 28], NB-IoT is used in the transmission of small amounts of data. It is standardized by 3GPP, connected to LTE infrastructure, and based on LPWAN. Using existing cellular infrastructures, it is a good candidate for IoT implementation by providing a standardized common platform for device connectivity. An important advantage of NB-IoT technology is its compatibility with LTE frameworks, GSM, UMTS and the 5G network. It is ideal for large coverage networks with minimal complexity. One of the greatest advantages of NB-IoT is its adaptability in complex situations such as work in rural areas. It is also considered green technology due to its energy characteristics, which is very important while working with a large number of devices or sensors. It allows you to connect many devices (more than 100,000). It uses a wide frequency band (180 kHz). Data rates are not especially high, up to 250 kbit/s. However, NB-IoT is not sensitive to delays, so it is used in delay-tolerant applications. It is based on the LTE protocol whose functionality it reduces to make improvement to IoT applications. It is used, for example, in smart parking, which is part of transport activity, and for the purpose of supervision and monitoring. In contrast, LTE-M has a higher delay (100-150 ms), which makes it a more powerful option.

According to [29], there are three defined ways of operating the NB-IoT network. Stand-alone mode is an autonomous mode that uses an independent frequency band that does not overlap with the LTE band. Guard-band mode is a mode in the protected band of the LTE network. In-band mode uses the LTE band for development and requires one PBR (Physical Resource Block) LTE band. This is the most commonly used mode. The NB-IoT network consists of five parts. An NB-IoT terminal represents IoT devices that have access to the NB-IoT network. The base station refers to the stations that need to support the defined working modes. The core of the NB-IoT network is used to connect the base station to the cloud IoT platform. The cloud platform is used to process various services and provide results to NB-IoT terminals. The Vertical Technical Center receives services, stores them in its center and takes control of the NB-IoT terminals.NB-IoT technology is still in the introduction phase. It is evolving by using and upgrading existing networks and it will take some time before it becomes accepted and developed around the world. As it is not yet fully developed in practice, LoRa and Sigfox, which are mature and commercialized technologies, are often still used.

Tab. 3 shows the technologies used by the IoT and compares the values of their essential parameters.

Table 3 Comparison of IoT technologies

	SigFox	LoRa	WLAN	ZigBee	WiMAX	LTE-M	NB-IoT	GSM	RFID
Spectrum	Unlicensed	Unlicensed	Unlicensed	Unlicensed	Unlicensed	Licensed	Licensed	Licensed	Unlicensed
Cellular	No	No	No	No	No	Yes	Yes	Yes	No
Range	Urban: 3-10 km Rural: 30-50 km	Urban: 8 km Rural: 22 km	10 m	100 m	50 km	Urban: 2-5 km	Urban: 1-5 km Rural: 10-15 km	<35 km	20 cm
Max data rate	100 bps	50 kbps	600 Mbps	50 kbps	75 Mbps	1 Mbps/1Mbps	250 kbps	<500 kbps	106-424 kbps
Bandwidth	100 Hz	500 kHz	20 MHz	2 MHz	20 MHz	20 MHz	180 kHz	200 kHz	200-400 kHz
Frequency band	868MHz (Europe), 915-928 MHz (USA), 433MHz (Asia)	868-915 MHz	2.4-5 GHz	868 MHz-2.4 GHz	2.3, 2.5, 3.4 GHz	1.4-20 MHz	700, 800, 900 MHz	850, 900, 1800, 1900 MHz	13.56 MHz
Standardization	Collaboration of ETSI	LoRa Alliance	IEEE 802.11	ZigBee alliance	IEEE 802.16	3GPP	3GPP	2G, 3G, 4G, LTE, CDMA	ISO
Interference immunity	Very high	Very high	Low	Low	High	High	High	Low	Low
Energy consumption	Low	Very low	High	Low	Medium	Low	Low	Medium	Medium
Cost	Low	High	High	Low	High	High	High	Medium	Low

After analyzing all options, the question arises as to how to choose the technology that will be most effective for the application of IoT. The parameters on which network quality depends are quality of service (QoS), battery life, latency, network coverage, scope, development model, and cost.

- **Quality of service**

QoS depends on the spectrum that is involved and the protocols that are used. For example, LoRa and SigFox use unlicensed bands and are based on the ALOHA asynchronous protocol. While they deal well with interference, they do not provide a very high quality of service. NB-IoT, which uses a licensed spectrum and the LTE protocol, stands out here. However, seizing the spectrum is very expensive. Therefore, when there is a need for better QoS, NB-IoT technology will be used, and otherwise, it is better to use e.g. LoRa.

- **Battery**

Battery life depends on power consumption of the device. NB-IoT has high power consumption, so SigFox or LoRa is a better option if battery life is an essential parameter in IoT applications. Due to the asynchronous LoRa protocol, devices can idle for as long as necessary and thus save battery power.

- **Delay**

NB-IoT applications require a small delay when transferring large amounts of data. If applications are sensitive to latency and do not send large amounts of data, e.g. LoRa would be a better choice.

- **Scalability**

The IoT needs to be able to connect an enormous number of devices, and all technologies applying it enable this. But NB-IoT provides an incomparably greater advantage, where it also achieves connectivity of up to 100,000 devices per base. It sends a much larger amount of data at the same time compared to other technologies.

- **Coverage and range**

Although NB-IoT is much more convenient when it is necessary to send a large amount of data, its coverage is only up to 10 km. It is deployed only within LTE infrastructure and not adapted for regions like rural areas that do not have LTE coverage. LoRa is a bit more flexible and has a range of up to 20 km, while SigFox has an even bigger range of up to 40 km.

- **Costs**

There are several cost types to consider. These are spectrum license costs, network setup and development costs, and end-device costs. Accordingly, NB-IoT is the most expensive option.

When it comes to logistics processes, it is necessary to enable machine automation, i.e. continuous monitoring and data collecting using sensors. According to [30], this requires continuous communication and a service of high quality. So, NB-IoT would be a good solution. However, if this is a large area, where many sensors are needed, and it is important to make sure that long-lasting batteries are used, then technologies such as LoRa and SigFox have an advantage. When it comes to warehouses, it is important to control parameters such as temperature, humidity, safety, goods flow, energy consumption, etc. For this, you need to use a lot of cheap sensors with good batteries, so LoRa and SigFox are the best options. As each technology has more multiple benefits, it is good practice to use hybrid solutions.

4 THE FUTURE OF LOGISTICS, THE 5G NETWORK AND OTHER TECHNOLOGICAL CHALLENGES

According to [31], the most advanced technologies such as NB-IoT are based on LTE, i.e., the 4G network. The more devices that need to be connected, the harder it is for the 4G network to provide full support. It is crucial to achieve a high data rate, which can go up to 1Gb/s maximum. It is possible to connect about 4,000 devices within a square kilometer, which contradicts the IoT idea (millions of devices connected in the same place). This creates the need for an even more efficient network, hence 5G. According to [32], 5G is a heterogeneous system that includes 4G, Wi-Fi, millimetre waves, and other wireless technologies. 5G offers high data rates between many connected devices, with an extremely small delay. That is very important for the development of IoT applications. The frequency band used by mobile networks (up to 3.5 MHz) is slowly becoming overcrowded. According to [33], 5G will allow operation ranging about 26 GHz.

According to [34], various parameters must often be monitored in logistics activities, which requires a large number of sensors. 5G will support for every meter of coverage up to 1,000 times more devices than the 4G network could with a 100 times higher data rate. High speeds, low delays, higher coverage, lower power consumption, and real-time actions execution are essential factors for the successful implementation of the IoT. Thus, the IoT becomes the key to the future development of logistics. A major challenge for logistics is the visibility of the supply chain. Without good enough supervision, information on the condition or location of goods is lost. With 5G it will be possible to monitor all data in real-time. Extremely low delays in 5G will be very suitable for autonomous transport actions that need fast feedback to execute all decisions promptly. Human errors that lead to loss of goods, mismanagement, and inefficiency are also common during the monitoring of logistic actions. Such problems will disappear with the implementation of IoT systems based on the 5G network. Amounts of data are rapidly growing, as well as customer demands. Those circumstance will demand applications that need faster and smarter, but also reliable architecture. It is very probable that the current IoT architecture will not be sufficient for next-generation IoT applications and upcoming services. Nowadays, most of the architectures are implemented in industry or smart cities, and by [35], these architectures are suitable for the time being, but they will not no longer be promising in terms of reliability and performance due to future challenges and therefore need to be re-examined. The fifth generation (5G) networks are taking into consideration the growth of IoT applications. Important contributions are made to the next generation of the IoT by connecting billions of intelligent devices which will allow the desired growth. For example, the existing cellular networks are not able to support the MTC communications (Machine Type Communication), but the 5G-IoT networks could provide this. In addition, 5G-IoT provides the fastest cellular network data rate with very low latency and improved coverage for M2M communication.

According to [36], the application of the IoT in logistics is expanding more and more. Therefore, it continues to face numerous technological challenges. An example of the current problem is the sensitivity of RFID technology to electromagnetic interference. In addition, there is also collision of containers that contain sensors. Thus, the location and identification of goods is difficult. Other problems such as signal attenuation or limited sensor battery life may interfere warehouse activities. Delays and data losses create low efficiency and high energy consumption. IoT technology is limited by vehicle selection and cargo optimization during transport. Attention should also be paid to working with data.

For huge amounts of data, there are also large requirements based on complex logistics processes. A particular challenge for the IoT is to preserve information to avoid privacy violation or data theft.

Today, efforts are being made to develop better algorithms against RFID sensors collisions, and new protocols are being proposed to identify unread data. Scientists are also working to optimize communication protocols to prolong sensor battery life. New technologies, like the 5G network, allow less latency and more coverage. With cloud technology, it is possible to solve complex situations in supply chain management, which provides flexibility and automation, and facilitates data review and sharing. In order to make logistics IoT systems as efficient and secure as possible, it is necessary to include new protocols and technologies such as M2M (Machine to Machine), BLE (Bluetooth Low Energy), Z-Wave, artificial intelligence, cloud technologies, Big Data, and others.

According to [37], IoT technology is reforming logistics and consequently driving profit. Improving logistics processes is key to the progress of any company. Therefore, the development of communication, sensor and mobile technologies is really important. Thus, the integration of logistics processes with the advancement of IoT technology will become more and more optimal.

5 CONCLUSION

As one of the most advanced technologies today, the IoT is widely applied in various scientific fields and economic activities, including logistics. Efforts are being made to optimize logistic processes, and this includes better control of goods and assets, monitoring the operation of warehouses, introducing automated work, monitoring the transport of goods and determining the best routes. Collecting a large amount of information, timely responses, automated device management, real-time data processing are the benefits that the IoT brings. All this significantly changes the flow of logistic processes and leads to increased efficiency as well as reduced costs. Companies around the world are trying to introduce the IoT as much as possible and use all its benefits for the advancement of logistics. Various technologies and standards can be used in the implementation of IoT systems, depending on the application needs. In logistics, the most common is the usage of wireless sensors, RFID technology, cloud technology, GPS, WLAN, and mobile networks. Wireless technologies such as SigFox, LoRa, ZigBee, and WiMAX are often applied in IoT systems. In recent times, efforts have been made to incorporate NB-IoT technology, which offers even better advantages for the further development of the IoT. The 5G network will bring great changes as it will enable the connection of an extremely large number of devices at high data rates. It will be a revolution in IoT technology, and thus in logistics.

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Authors' contacts:

Dr. Dominika Crnjac Milić, Full Professor
(Corresponding author)
Josip Juraj Strossmayer University of Osijek,
Faculty of Electrical Engineering, Computer Science and Information Technology in Osijek,
Kneza Trpimira 2B, 31000 Osijek, Croatia
+385 31 224 681, dominika.crnjac@ferit.hr

Irena Dujmenović, bacc. ing. el.
Josip Juraj Strossmayer University of Osijek,
Faculty of Electrical Engineering, Computer Science and Information Technology in Osijek,
Kneza Trpimira 2B, 31000 Osijek, Croatia
+385 97 682 4923, irena97ms@gmail.com

Marina Peko, MEng.
Josip Juraj Strossmayer University of Osijek,
Faculty of Electrical Engineering, Computer Science and Information Technology in Osijek,
Kneza Trpimira 2B, 31000 Osijek, Croatia
+385 495-417, marina.peko@ferit.hr

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Major Cloud Computing Security Challenges with Innovative Approaches

Fudhah A. AlSelami

Abstract: Cloud computing is the most favored contemporary era as it has the cap potential to decrease its costs related to computing which improves its pliability and extensibility for further computer processes. Among the past some years, cloud computing has been well superior as a hopeful idea for business organization to one of the additives of the IT organization it really is fastest growing. There are important troubles like protection which the IT agencies take into difficulty that misplaced with the heavy insertion of cloud computing Technology. Though records may be saved in any vicinity. The important reality is Storage of records is saved best with inside the vicinity of the clients that's been the numerous varieties of worries created. In cloud computing region the maximum argued hassle is especially Security. This study mainly intends to analyze and address the major cloud computing security challenges with innovative approaches. To meet that aim, a range of scientific methods, including descriptive, analytical, observation and comparison are taken into account. Given the results, the major key to a success cloud computing projects is reaching stability among the commercial enterprise blessings and the hidden capacity dangers that can affect efficacy.

Keywords: challenges in cloud security; cloud computing; logistic regression; security in cloud

1 INTRODUCTION

Cloud safety, moreover referred to as cloud computing safety, comprises a difficult and rapid of rules, strategies, controls, and generation that art work altogether to defend cloud-based completely systems, reality, and configuration [1-3]. Those protection capabilities are configured to defend cloud reality assist governing compliance and defend clients' privacy further to establishing validation laws for person clients and tools [4-6]. From validating get proper of access to selecting traffic, cloud safety can be arranged to an appropriate desire of the business. And because of the reality the ones principles can be managed and configured in a particular place, control up above are reduced and IT businesses authorized to recognition on one-of-a-kind business areas [2, 7, 8].

Cloud computing (CC) is on-name for get proper of access to computing property—programs, servers, development tools, records storage, capacities of network, and many—hosted at a much-flung records centre managed thru manner of approach of a cloud services issuer (CSP) [9-12].

2 METHODS

To gratify the study's objectives, a range of scientific methods, including descriptive, analytical, observation and comparison are taken into account.

Main characteristics of cloud computing include [6, 13, 14]:

1) **On-demand self-services:** The services of Cloud computing doesn't require any man power managers, character are capable of provision, monitoring and controlling computing property as desired.
2) **Broad network accesses:** Those services are typically supplied over desired devices and networks which are heterogeneous.
3) **Rapid elasticity:** The cloud Computing advantages must have IT assets which might be capable of scale in and out speedy and on as wished basis. Whenever the person requires offerings, it's far furnished to them and it's far scale out as quickly as its needs overcomes.
4) **Resources' pooling:** The Information Technology useful resource (example: servers, networks, programs, and offerings) gift are moved through a couple of programs. Many customers are furnished carrier from a identical bodily useful resource.
5) **Measured service:** The beneficial useful utilization of resources is pursued for each occupant and software, it provides the man or woman and the beneficial useful resource supplier with an account of what utilized. That is finished for a few causes, such as billing monitoring and efficient utilization of beneficial useful resources (Fig. 1).

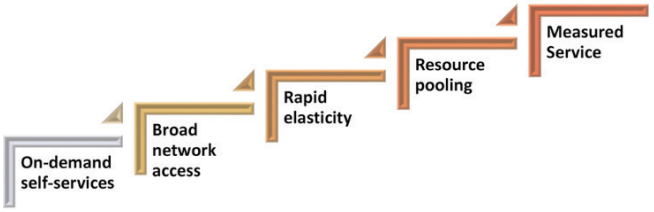

Figure 1 Features of Cloud Computing [7]

3 RESULTS AND DISCUSSION

Cloud infrastructure includes garage devices, platform virtualization, cloud control software, servers, deployment software, and networks (Fig. 2).

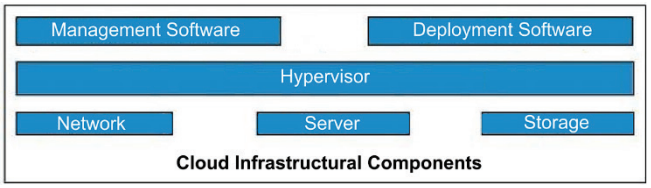

Figure 2 Infrastructure's Components [8]

A) **Hypervisor:** Hypervisor is a low-level or firmware software program acting as a Virtual Machine Manager. That permits to percentage the single physical instance of cloud re-assets amongst many tenants.
B) **Management Software:** It permits to keep and manipulate the infrastructures.
C) **Deployment Software:** It permits to installation and merge the utilities in cloud.
D) **Networks:** It seems crucial element of cloud infrastructures. It permits to link cloud services over the net. Moreover, it seems likely to deliver network as software programs over the net, meaning that customers can personalize the protocol and network path [6, 15, 16].
E) **Servers:** The server permits computing the useful resource offers and sharing one of kind services collectively with useful resource allocation and allocation de-, monitoring the re-assets, imparting protection, and so forth.
F) **Storage:** Cloud has more than one replica of storage. In case a storage re-assets fails, that may be extracted from another one, making cloud computing further trustworthy.

3.1 Infrastructural constraints

The basic guidelines and regulations that cloud infrastructure need to execute are proven with inside Fig. 3:

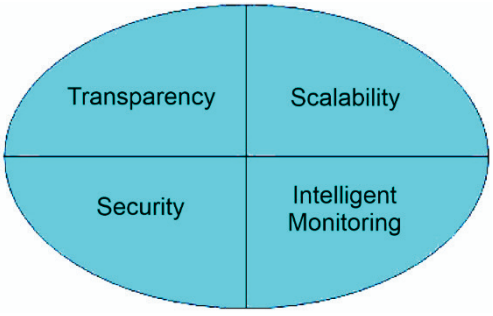

Figure 3 Restrictions for Implementation [9]

A) **Transparency:** Virtualization is regarded as an essential element to percentage re-assets in the environment of cloud. Nonetheless, it isn't feasible to meet the decision for with single server or resource. Hence, there ought to be transparency in re-assets, software and load balancing, simply so that one is able to scale them on name for.
B) **Scalability:** Scaling up a software shipping solution isn't much clean as scaling up a software since it consists of configuration overhead or perhaps re-architecting the network.
C) **Security:** The mega statistics centre with inside the cloud ought to be safely designed. Moreover, the manipulate node, and get right of entry to element in mega statistics centre, moreover requires security [12, 17].
D) **Intelligent Monitoring:** To benefit scalability and transparency, software solution shipping may require a good way to clever monitoring.

3.2 Significance of the Security of Cloud Computing

Cloud protection gives several advantages, such as [13, 18, 19]:

- **Central protection**: CC organizes records and applications; cloud safety centralizes safety. Cloud-based definitely industrial organisation networks embody multiple devices and endpoints able to be tough to govern while coping with BYOD or shadow IT. Handling the ones entities centrally boosts traffic assessment and net filtering. Disaster healing schemes additionally may be completed and actioned without troubles while handled in a unmarried region.
- **Reduced expenses:** A striking advantage of using cloud garage and protection is that it gets rid of the want to spend money on devoted hardware. Not handiest does this lessen capital expenditure, however it additionally reduces administrative overheads. Where as soon as IT groups had been firefighting protection problems reactively, cloud protection promises proactive protection functions that provide safety round the clock with very little human being meddling.
- **Reduced Administration:** While choosing an amazing cloud services business enterprise or cloud safety platform, you could say farewell to manual safety configurations and nearly perpetual safety updates. Those obligations might also additionally have a massive drain on resources, but at the same time as you flow into them to the cloud, all safety control takes region in an unmarried location and is sincerely handled on the behalf of you.
- **Reliability:** Cloud computing services provide the remaining in dependability. With the right cloud protection functions in region, clients can effectively get proper of access to information and applications with inside the cloud (Fig. 4).

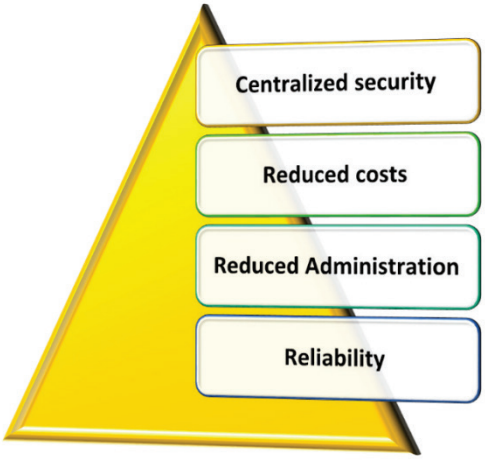

Figure 4 Security Significance [10]

3.3 Challenges Involved in Cloud Computing Security

On the basis of the Cloud Security Report, the best rating danger became misconfiguration, with roughly 68.0% of businesses bringing up that as their biggest concern [20, 21]. Misconfiguration takes vicinity whilst a cloud-associated gadget, asset or tool, isn't configured adequately, consequently endangering the gadget and revealing it to a capacity assault or records leak. That hazard became accompanied through account hijacking (50%), insecure interfaces (52%), and unauthorized get right of entry to (58%). As effective and progressive because the cloud is, it's additionally complicated and ever changing. From a protection perspective, that generates several loopholes and challenges [11, 22]. The availability of corporation records draws many hackers who try to have a look at the systems, locate flaws in them, and make the most them for his or her benefit (Fig. 5) [14, 23].

Figure 5 Security Challenges [18]

3.3.1 Denial-of-Service and DDoS Issues

A DDoS or allocated denial-of-company attack is a spiteful strive by hackers in order to sabotage the regular functioning of your network or company by disrupting your servers with multiple web page visitors. The aim is making your server out of order to its meant users [15].

Detect: To save you an allotted assault, your protection provider has so that it will distinguish among an excessive extent of actual site visitors and a real assault.

Respond: While an attack is founded, your safety network responds through strangling malicious bot web website online traffic at the same time as leaving everyday web website online traffic.

Route: So as to avoid a provider denial, your network requires to cleverly course the web website online traffic into conceivable chunks to prevent your servers' overwhelming.

Adapt: The safety network wants to decorate over the years as it sounds and accepts to attack designs [16].

3.3.2 Loss of Data

While employer crucial data is transferred into the cloud, it's perceivable to be worried about its safety. Losing cloud statistics, each by human error and unintentional deletion, malicious tampering might be catastrophic for an agency employer. Normally DDoS attacks are simplest a diversion for a bigger opportunity, which includes a try and thieve or remove statistics [17]. Obviously, preserving get proper of access to your statistics and preserving it stable at every diploma is a must. This is the main reason to launch a strong statistics loss prevention (DLP) scheme as a part of the cloud safety approach [20].

Backup: The efficient means to stop records loss is to frequently again it up so that you hold ways to retrieve or get higher it with inside the loss event. [19]

Utilize DLP software: With the aid of that program, you may automatize your backup and loss prevention approaches so that your protection functions do not fall thru the cracks.

Do a risk evaluation: Audit your records to discover wherein and the manner your records is stored on the cloud. Once you have were given an inventory of your records storage, create records go along with the float map to recognize your records techniques and come to be aware about ability vulnerabilities.

3.3.3 Violations of Concurrence

Concurrence is one in every of the largest barriers several corporations face whilst identifying if or not to undertake cloud-primarily based totally operations. Regulatory controls cognizance closely on cloud protection, and Concurrence violations could hold a full-size poor effect to your enterprise and backside line [21].

Operational readability and consistency: To pass into the cloud, it is vital emigrate your operational strategies easily into the environment of cloud. The extra regular you're on your cloud control and operations, the less difficult it's far to apprehend and accurate protection troubles and reply to audits with correct report.

Data protection and visibility: Prior to the cloud, it became clean to find your information with inside the information centre. Today, information is unfolded throughout servers and a rising number of cell and allotted workforce. This introduces demanding situations for corporations that ought to observe strict information residency guidelines in a worldwide market. Getting a clean image of your information is an increasing number of vital and an increasing number of difficult. In addition, the extra allotted your information (mainly throughout unofficial servers and programs, additionally called Shadow IT), the more the chance on your information protection [23-25].

Concurrence responsibility: Another project of protection and Concurrence is figuring out who's surely chargeable for making sure you satisfy the ones demands. The degree of provider and the cloud company you pick out would have an effect on what obligation you need to meet compliance guidelines and what kind of your provider company will control compliance for you. Explaining those roles and making sure there aren't any gaps on your

compliance method and strategies is important for ensuring you gratify all guidelines.

3.3.4 Data Breaches

An information breach is whilst personal records is extracted and accessed with no authorization. It influences the effect to popularity and accept as true with of partners or clients. Regulatory implications which can bring about economic loss [23].

Application of the Principle of Least Privilege (PoLP): LP is the exercise of limiting get right of entry to rights for users, debts, structures, and strategies to handiest the minimal assets had to carry out recurring duties and obligations. The intention is to lessen the danger of protection breaches through restricting get right of entry to handiest individuals who want it. Through imposing PoLP, corporations can substantially lessen possibilities for exploitation, and enhance compliance throughout the community.

Utilization of multi-issue authentication: Multi-issue authentication (MFA) is a protection approach for logins that calls for or extra credentials from a consumer to affirm their identification earlier than granting get right of entry to. This is a easy however powerful manner to extra tightly steady your information and make stronger your get right of entry to factors in opposition to capacity hackers.

Encrypt information at relaxation: Data is at relaxation whilst it isn't actively utilized and is saved on a tough drive. When that information is typically covered through primary perimeter defences like firewalls, encrypting your tough drives (and different information at relaxation) provides every other protection layer.

3.3.5 Indicators and Notifications

Understanding and right conversation of protection hazards is a basis for community protection and the equal is going for cloud computing protection. Alerting the proper internet site or software managers as quickly as a chance is recognized need to be a part of a radical information protection and get right of entry to control plan. Speedy mitigation of a chance is based on clean and activate conversation so steps may be taken through the right entities and effect of the chance minimized.

Automate protection indicators and notifications: While it involves protection, automation is a friend of yours. Functioning at the cloud affords several possibilities to enforce automation in order to growth performance and decrease human error. To construct out the cloud protection method, make certain to consist of computerized protection indicators and notifications on your strategies. A computerized protection notification machine will warn you in actual time to capacity or instantaneously threats, which include assaults, or vulnerabilities.

3.3.6 Hijacking Account

Lots of human beings hold extraordinarily susceptible password protection, which include password reuse and using susceptible passwords. That hassle exacerbates the effect of phishing assaults and information breaches because it permits an unmarried stolen password for use on more than one unique debts. Account hijacking is a chance wherein malicious attackers' advantage get right of entry to and abuse debts which might be exceptionally privileged or touchy. In cloud environments, the debts with the best dangers are cloud provider debts or subscriptions.

Implement sturdy get right of entry to methods and controls: When fragilities in the era itself are an extreme worry, a large danger on your information protection comes out of your human assets. Lax get right of entry to methods and controls make it clean for hackers to sneak into your structures and wreak havoc. Create sturdy methods for get right of entry to control (which include multi-issue authentication and least privilege) to limit danger round get right of entry to factors.

3.3.7 Cyberattacks

Cybercrime is deemed as an enterprise, and cyber-criminals select their objectives mainly on the basis of the predicted profitability in their assaults. Cloud-primarily based entirely infrastructure is immediately handy from the general public Internet, is frequently inadequately secured, and carries a high-quality deal of touchy and treasured information. In addition, the cloud is utilized by several unique organizations, which means that a success assault can probably be repeated usually with an excessive success possibility. Consequently, corporations' cloud deployments are a not unusual place goal of cyberattacks.

Solutions for this issue include:

1) Identity robbery,
2) fraud,
3) extortion Malware,
4) phishing,
5) spamming,
6) spoofing,

consisting of laptops or cell gadgets, Denial-of-provider and allotted denial-of-provider assaults, Breach of get right of entry to Password sniffing, System infiltration, Website defacement, Private and public Web browser exploits, Instant messaging abuse, Intellectual property (IP) robbery or unauthorized get right of entry.

4 CONCLUSIONS

Undauntedly, CC allows IT organizations use diverse strategies to boost and steady utility overall efficiency in a cost-powerful way [25]. Furthermore, simply due to the fact the software program can run in a Virtual system does now no longer suggest that it plays nicely in cloud surroundings necessarily. The fundamental key to a success cloud computing projects is reaching stability among the commercial enterprise blessings and the hidden capacity dangers that can effect efficacy. Cloud carriers regularly have numerous effective servers and assets a good way to offer suitable offerings for his or her customers however cloud is

at hazard much like different Internet-primarily based totally era. In the opposite hand, they're additionally susceptible to assaults inclusive of effective DDoS assaults comparable different Internet-primarily based totally era. As a solution, cloud carriers can upload greater aid to defend themselves from such assaults however alas there may be no protection in opposition to an effective DDoS assault which has true sapience. These troubles which mentioned on this paper are the primary motives that purpose many organizations that have an aircraft immigrate to cloud pick the usage of cloud for much less touchy facts and keep critical facts of their personal neighbourhood machines. In addition, consequently, moving in the direction of cloud computing need to remember numerous factors and maximum critical of them is deemed security [24].

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Author's contacts:

Fudhah A. AlSelami
Department of Management Information Systems,
College of Business, University of Jeddah,
Al-kamel Governorate Branch, Jeddah, Saudi Arabia
falsulami@uj.edu.sa

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Automation of Production Line in Order to Increase the Productivity

Dejan Vapski*, Zoran Pandilov

Abstract: The main goal of this research is to demonstrate a design solution of upgrading of a production line through automation of one section of the line. With this automation, the productivity was increased with lower costs per produced product. A machine for packaging was designed, which is used for final processing of the profile studs. This automation known as partial automation, where not all elements of the system are automated, is first step and it will obtain a possibility for further automation of the production line in order to reach a full automation process. Due to the very short time of return of investment, the crucial benefit of this automation is possibility of implementation in other plants of the company, which will multiply the benefit and provide more competitiveness on the market, due to the decrease of the production costs and improvement of the health and safety standards.

Keywords: automation; improvements; packaging; productivity; upgrading

1 INTRODUCTION

Automation enables application of the modern technologies in the manufacturing processes, higher productivity and increasing the company competitiveness on the market [1-3]. The basic reasons for the automation are the external demands, the continual changes that surround the process and internal factors, concerning the organizational and human resource level [4, 5].

The conceptual understanding for an automated system is being changing and at the same time it differs from the basic understanding for automation [6-11].

The industrial or manufacturing engineer is usually responsible for using the latest and the best technology on the safest and most economic manner in the process of manufacturing products. This responsibility requires an enormous knowledge and experience. Due to the continuous changing of technology, the knowledge can never be considered as completed and enough [12-14].

Many engineering applications involve some element of uncertainty [15-20]. From the other side, the modern production, requires daily and complete continuous operation of the equipment. Fulfilling these conditions is only possible, if the reliability of the equipment is set at a very high level and in the same time is enabled the reduction of the production time for a unit product. In order to achieve this goal, it is necessary to know the specifics of the production process and the technical solutions that are applied. During the production process, there is very often a need for a rapid change in the production program in order to meet the demands of the market, taking into account the stock situation and the variety of finished products. The various constructive solutions in practice showed different results in terms of the quality of the finished products and the effectiveness of the production plants under specific conditions of exploitation.

In this paper it will be presented a constructive solution - upgrading and automation of a machine for the production of dragged profiles made of galvanized sheet metal.

The research and constructive solution that will be presented in this paper demonstrates innovative upgrading and adaptation of a galvanized sheet metal production plant, through the implementation of an appropriate analysis of the efficiency of the machine and improved safety and ergonomic conditions for the operators.

The constructive solution that will be presented is an original by design and performance, and it is applied in an existing plant for the production of traction profile studs.

2 PRODUCTION PROCESS BEFORE AUTOMATION: DESCRIPTION AND ANALYSIS

Defining system performance measures is a critical step in the development of a project. The performance measures are defined before building a model. A performance measure may be defined as a metric for quantifying efficiency and/or effectiveness [21-24].

On the Fig. 1 below is presented the production line before automation.

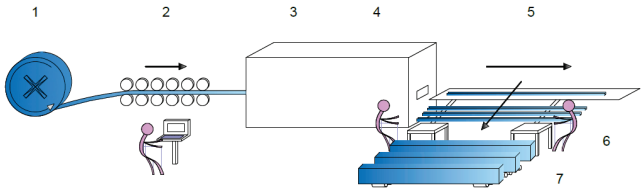

Figure 1 Production line before automation

The production of the metal profiles was operated by 1 (one) shift manager, 2 (two) operators and it was based on 7 (seven) steps:

1) **Unwinding of the steel sheet coil** – the sheet was uncoiled and dragged through the profiling rollers in order to be formed in final shape. The system worked discontinuously which means that after the coil was completely uncoiled, the production stopped and the next coil was set on the position for next production start.

2) **Profiling** – dragging the sheet through a set of rollers and the requested shape of the profile was reached. Depending on the type of the profile, there were different kind of roller sets.

One set had 8 to 12 stations. Each station maked step forward until the requested final shape.
Final station performed the calibration to the final dimensions.
3) **Punching station** – in this section the H hole was made on some of the profiles.
4) **Cutting station** - at this point, the continuous profile was cut on the requested length. The cutting tool moved on X-axes and Y-axes in the same time depending on the speed of the production line. After this operation, there was a speed-up roller, which pulled the cut piece and sent it to the next station.
5) **Cross end** – the cut piece slided longitudinal and cross on a surface which was positioned on a falling angle. At the end of this station, the profiles were gathering and the two operators paired them. The pairing process of the profiles is presented on Fig. 2.
6) **Strapping station** – created a small bundle. The two operators were preparing the defined bunch of profiles, lifting them on the strapping machine desk and processed the strapping. After that, the operators lifted the small bundle and put it down on transportation rollers.
7) **Big bundle transporter** – the small bundles were stacking in combination for obtaining a big bundle. The third operator was packaging the big bundle, strap it and after that the same operator taked the big bundle with a forklift and stored it in the warehouse.

- Observation and analyses of the production process before automation was done. Following topics of the process has been observed and analysed:
- Production line utilization
- Shift efficiency
- Production costs.
- Health and safety aspects.

The production line before automation was a concept operated by 3 persons, 1 shift manger and 2 operators on the end of the line. The shift manager had to organize the shift, changing the coil, adjusting the profile dragging station, quality control, big bond handling and storing the finished goods in warehouse. The two operators had a duty to pair the profiles, make the small bundles and to prepare the small bundles into a big bundle. They were processing in their shift the whole amount of steel, which was dragged to profile. They performed the same operations during the whole shift. The organization had no possibility to rotate the operators. The same operators had to do the same job the whole time. Because of that, sometimes operators were slowing down the speed, which impacted negatively to the productivity.

The production line was constructed for production with maximal line speed of 120 m/min. The declared speed was not able to reach for each type of profile due to following reasons:

1) Additional operation on some types such as H punching.
2) Length of the profiles: the shorter the profile was, the slower speed could be used, because of the collision of the cutted peace with the upcoming peace – shorter interval.
3) The size of the profiles: the wider the profile was, the slower speed was used due to heavier work for operator.

During the observation and gathering the data and information, following data came out as results:

- Number of persons per shift: 3 persons
- Max. achievable production speed: 110 m/min
- Average production speed: 82 m/min
- Number of changes of coils/shift 15 times
- Duration of a coil change: 5 min
- Number of changes of tools: 0.37 times
- Duration of one tool change 60 min
- Shift duration: 8 h
- Lunch break: 30 min
- Theoretically production time: 450 min
- Effective production time per shift: 352.8 min
- Shift utilization: 78.4 %
- Shift production amount: 28929.6 m
- Productivity per employee: 9.643.2 m/employee
- Employee costs shear: 1.9 %

Table 1 Advantages and disadvantages of the existing production process

Process analysis	
Advantages	Disadvantages
Simple equipment	Physical labour
Low maintenance costs	Lost time for coil change
	Higher employee costs
	Low utilisation of the shift manager

Productivity Measurement and Enhancement System (ProMES) was applied as a tool to analyze the effectiveness of existing system. ProMES is a highly effective management system for measuring and improving the productivity of work units within organizations through performance measurement and feedback [25-28]. The definition of productivity is used: how effectively an organization uses its resources to achieve its goals [29-32].

According to the analysis, a list of possible improvements was done, in order to transform the disadvantiges to advantage:

1. Automation of section 5 and 6 (Fig.1)
2. Automation of section 7 (Fig.1)
3. Automation of coil change – section 1 (Fig.1)

3 DESIGN AND CONSTRUCTION OF UPGRADES FOR AUTOMATING THE PRODUCTION PROCESS INTRODUCTION

Considering that the improving productivity and health and safety issues are the most important topics, the management of the organization has decided that the automation of the section 5 and 6 (Fig. 1) should be the first step of improvement of the process. Flexibility in manufacturing is a great concern fopr every company, because today on the market exists a great competitivness. In the fast developing industries flexibility becomes necessity. When we speak about flexibility, its concept have different meaning each time. Flexibility is defined as a

different level hierarchy, starting from resources, system flexibility, production performance and overall competitiveness of the company [6-11]. First of all we observed the production line. On Fig. 2 is presented the section 5 and 6 from the production line before automation.

For the new concept was necessary manufacturing of following assemblies:

1) Longitudinal and cross conveyor incl. gravitation forces controller and positioners
2) Profile turner and matching element
3) Small bundle preparation station
4) Small bundle strapping station
5) Small bundle transportation and stacking element

Following conditions were requested to be fullfiled:

- Health and safety standards
- Full automatically control
- PLC synchronization with the existing machine

Figure 2 Section 5 and 6 of the production line before automation

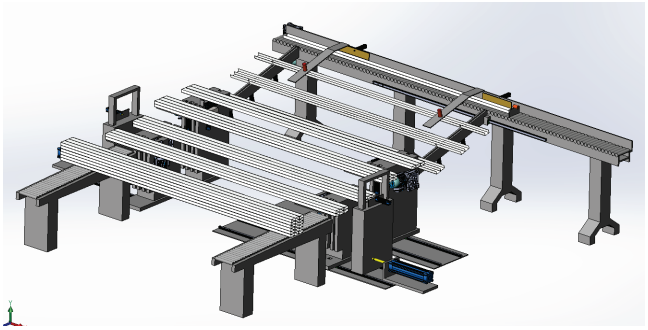

Figure 3 Upgrade of the packaging section

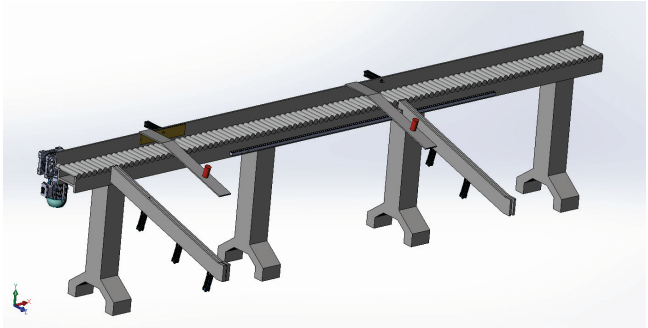

Figure 4 Longitudinal and cross conveyor

The Fig. 3 presents the concept of the upgrading of the profile packaging section. This concept was fully manufactured and installed in the investor plant.

The Fig. 4 presents the longitudinal and cross conveyor, including gravitation forces controller and positioners.

The gravitation forces have to be controlled because of the different range of the weight of the profiles in kg/m. Two stopping stations on each side of the sliders were planned (Fig. 5).

Figure 5 Gravitation forces controllers – stoppers

The stoppers are controlled through PLC and they can be adjusted by controlling the opening time (Fig. 6). In addition, the length of the profiles could be adjusted.

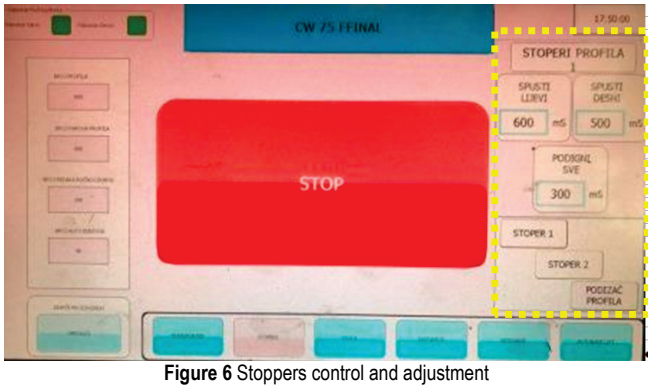

Figure 6 Stoppers control and adjustment

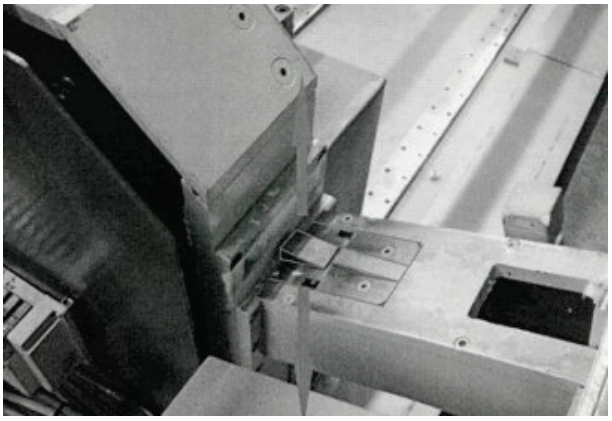

Figure 7 Profile positioner - fixed

The positioning of the first profile is very important for further function of the machine. If the first profile is not on the requested position, the turner will not succeed to pair it with the second piece. One aggravating circumstance is the

different geometry of the profiles, as well as their dimensions and specific weight. The problem was solved with designing different positioners for each type of profile (Fig. 7 and Fig. 8).

For UD profile which has the smallest dimensions and which is lighter, the special magnetized holder which rotates in one point through a pneumatic actuator was designed (Fig. 8).

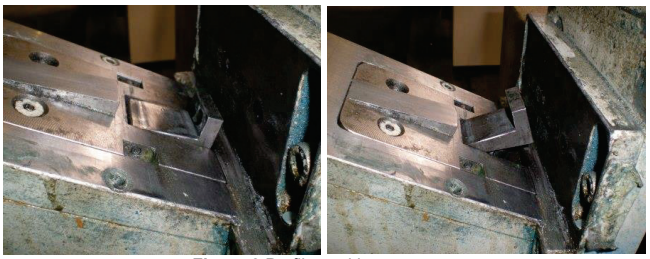

Figure 8 Profile positioner - rotary

The matching of two profiles was reached by the profile matching and turner machine. The drive elements move the carriers on X and Z axes, which provides lifting of the matched profiles and positioning them for the next step – preparation of small bundle. The carriers have different design, depending on the type of the profile and various dimensions.

Profi-bus communication protocol is widely used in pneumatic and electric drives. It is common to apply one profi-bus among many field-buses in the controller in order to provide multi-axis position control via high speed serial-bus. This allows communication of a far higher density of information to and from the controller, and also enables the realization of multivariable sensors and integrated sensing, control and actuation in a single system.

In both pneumatic and electric drives, this capability opens an opportunity to automate processes, covering larger range of parameters, such as position, pressure, speed, flow, etc. In addition, communication with external devices and systems is also possible, without additional cablings, which further enhances the implementation of a fieldbus-based controller [33-35].

The Fig. 9 presents the profile matching and turner.

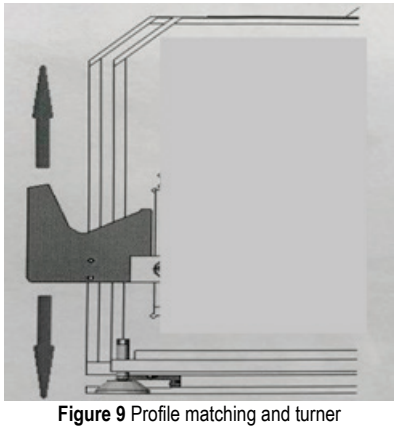

Figure 9 Profile matching and turner

Apart from the design, for the success of this operation, the speed of movement of the carrier is essential. The carriers are powered by three different speeds. The speeds are adjustable (Fig. 10) and they vary depending on the type of the profile.

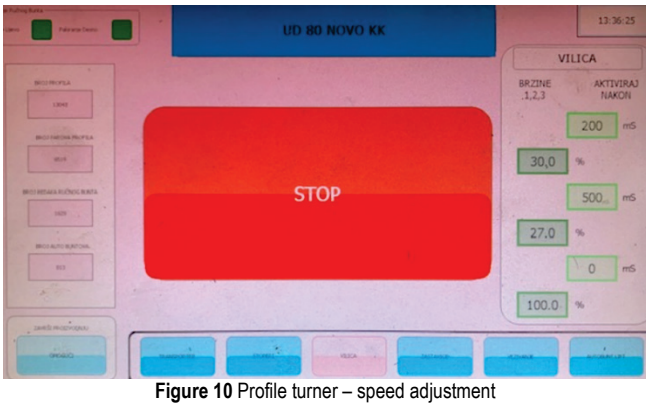

Figure 10 Profile turner – speed adjustment

The small bundle stacking station (Fig. 11) is composed of a single stopper, a lifting device that allows the stacking of multi-row profiles and a push button which using pneumatic actuator transmits a small cable to the binding station.

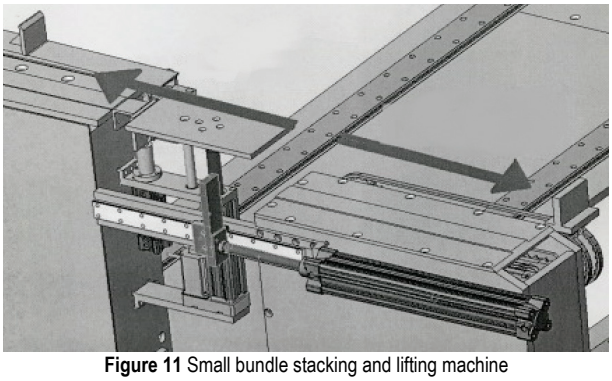

Figure 11 Small bundle stacking and lifting machine

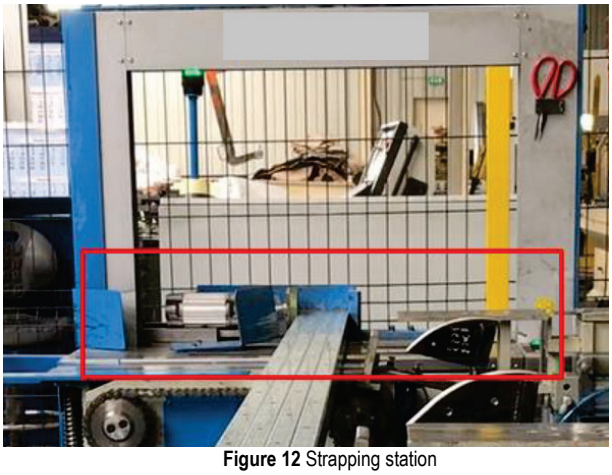

Figure 12 Strapping station

The main role of the strapping station (Fig. 12) is to tie a small bundle. The strapping station consists of strapping machines which are moved longitudinally. In strapping station there is an embedded system for handling the bundle

before strapping. The longitudinally movement is enabled by pneumatic actuators.

In the small bundle transportation and stacking section the already strapped small bundle is moved to the lifting station and set one above the other. When the number of small bundles in a column is reached, the lifting machine lifts the column down to the requested position. After that the column will be pushed in cross direction to the roller conveyors – left and right through a pusher (Fig. 13).

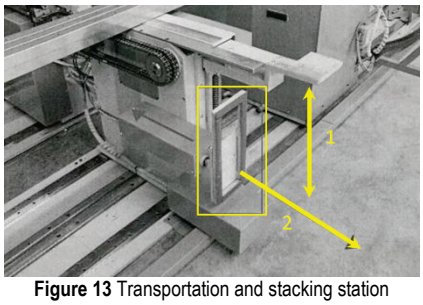

Figure 13 Transportation and stacking station

4 ANALYSIS OF THE RESULTS OBTAINED AFTER THE UPGRADING

On Fig. 14 is presented a new concept of the automated production line.

The Tab. 2 contains data based on the analysis of the results obtained after 8 months after the automation and commissioning of the production line for the metal profiles production. The presented data shows a comparison of productivity and other key performance indicators before and after automation.

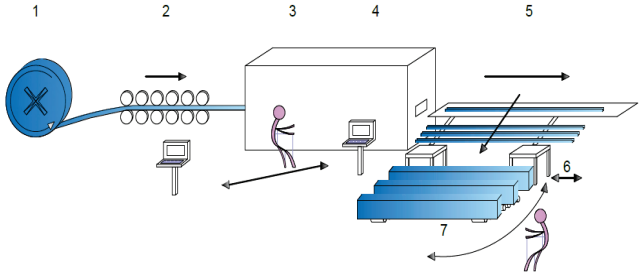

Figure 14 New concept – Automated production line

Table 2 Data for the production process before and after the automation

Topic	Unit	Before	After
Number of staff per shift	person	3	2
Max. achievable production speed	m/min	110	105
Average production speed	m/min	82	85
Shift production amount	m	28.929	30.120
Productivity per employee	m/person	9.643	13.406
Employee costs shear	%	1,04 %	0,75%

All data after automation, exept maximal acivable production speed, have shown better results. The decrease of maximal achivable production speed is less than 5%, but what is more important the average production speed after automation increased about 4 %.

The only one disadvantage, decrease of maximal achivable production speed, should be easily overcome by replacing the pneumatic actuators (Fig. 15) which drive the strapping machines, with servo motors that will enable:

1) Greater speeds of small bonding machines.
2) Easy control of motion, because they will be able to define start and stop cycles.

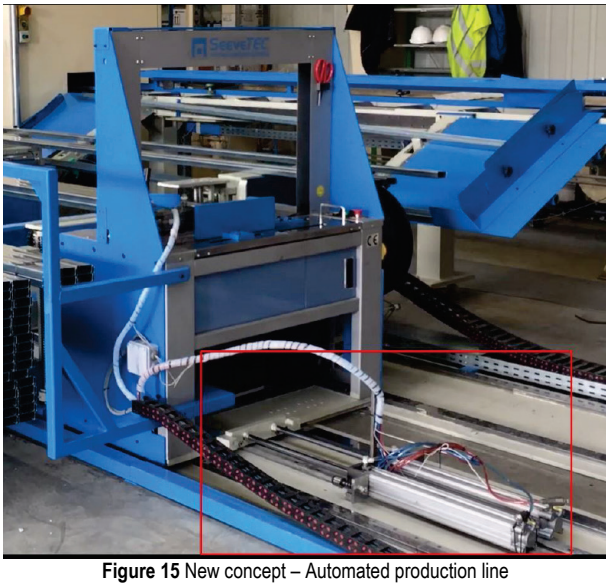

Figure 15 New concept – Automated production line

The health and safety standards in the automated production line were improved through machine guarding.

Machine guarding is one of the most relevant areas of local legal requirements, applied in industrial automation systems. In machine guarding standards, the most significant area in automated systems is guarding the place of processing [37-39].

The automated-system designer should consider the safety aspects of manufacturing systems in the design phase. The hazards of the human/machine interface should be removed before the system is built [37-39].

Following types of guarding were installed in the above-mentioned partly automated production line in order to enable preventive protection of the danger zones on machines:

1) Gates: They close and remain closed during the entire cycle.
2) Presence-Sensing Devices: Infrared systems for sensing objects that penetrate and enter in the danger zone.
3) Interlock mechanisms: Interlock mechanisms preventing a machine to operate, if any part of the machine is in an unsafe mode. The machine will not operate if the door is open.

5 CONCLUSION

This innovation project is an excellent example how automation, even of one section of the production line, influence on the increasing of the productivity accompanied with lower costs per produced product and improvement of health and safety standards in one company.

In addition, due to the very short time of return of investment, the crucial benefit of this innovation automation project is possibility of its implementation in other plants of the company. This will multiply the benefit and provide more competitiveness of the company on the world market, due to the decrease of the production costs.

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Contact information:

Dejan Vapski, MSc
(Corresponding author)
Šibenskih vatrogasaca 12, 22000-Šibenik, Croatia
E-mail: dejan.vapski@gmail.com

Zoran Pandilov, Dr. Sc. Full Professor
Faculty of Mechanical Engineering,
University "St. Cyril and Methodius",
Karpos II, P.O.Box 464, MK-1000-Skopje, Republic of N. Macedonia
E-mail: zoran.pandilov@mf.ukim.edu.mk

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Article Title Only in English (Style: Arial Narrow, Bold, 14pt)

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Ivan Horvat, Thomas Johnson, Marko Marić (Style: Arial Narrow, Normal, 10pt)

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Abstract: Article abstract contains maximum of 150 words and is written in the language of the article. The abstract should reflect the content of the article as precisely as possible. TECHNICAL JOURNAL is a trade journal that publishes scientific and professional papers from the domain(s) of mechanical engineering, electrical engineering, civil engineering, multimedia, logistics, etc., and their boundary areas. This document must be used as the template for writing articles so that all the articles have the same layout. (Style: Arial Narraw, 8pt)

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1.1 Subtitle 1 (Writing Instructions)

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The document format is Letter with margins in accordance with the template. A two column layout is used with the column spacing of 10 mm. The running text is written in Times New Roman with single line spacing, font size 10 pt, alignment justified.

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Body of the text is divided into chapters and the chapters are divided into subchapters, if needed. Chapters are numbered with Arabic numerals (followed by a period). Subchapters, as a part of a chapter, are marked with two Arabic numerals i.e. 1.1, 1.2, 1.3, etc. Subchapters can be divided into even smaller units that are marked with three Arabic numerals i.e. 1.1.1, 1.1.2, etc. Further divisions are not to be made.

Titles of chapters are written in capital letters (uppercase) and are aligned in the centre. The titles of subchapters (and smaller units) are written in small letters (lowercase) and are aligned left. If the text in the title of the subchapter is longer than one line, no hanging indents.

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Typographical symbols (bullets), which are being used for marking an item in a list or for enumeration, are placed at a beginning of a line. There is a spacing of 10pt following the last item:

- Item 1
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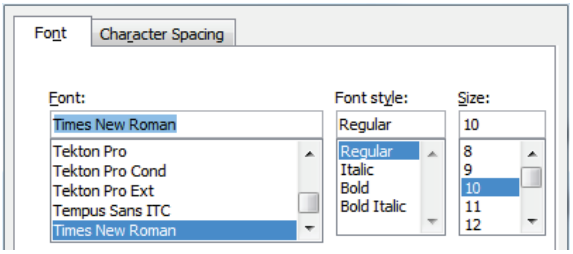

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When describing figures and tables, physical units and their factors are written in italics with Latin or Greek letters,

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Table 1 Table title aligned centre

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	1	2	3	4	5	6
ABC	ab	ab	ab	ab	ab	ab
DEF	cd	cd	cd	cd	cd	cd
GHI	ef	ef	ef	ef	ef	ef

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Equations in the text are numbered with Arabic numerals inside the round brackets on the right side of the text. Inside the text they are referred to with equation number inside the round brackets i.e. ".... from Eq. (5) follows ...." (Create equations with MathType Equation Editor - some examples are given below).

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$$F_{\text{avg}}(t, t_0) = \frac{1}{t}\int_{t_0}^{t_0+t} F\left[q(\tau), p(\tau)\right] \mathrm{d}\tau, \tag{1}$$

$$\cos\alpha + \cos\beta = 2\cos\frac{\alpha+\beta}{2}\cdot\cos\frac{\alpha-\beta}{2}, \tag{2}$$

$$(\boldsymbol{AB})^{\mathrm{T}} = \boldsymbol{B}^{\mathrm{T}}\boldsymbol{A}^{\mathrm{T}}. \tag{3}$$

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Variables that are used in equations and also in the text or tables of the article are formatted as *italics* in the same font size as the text.

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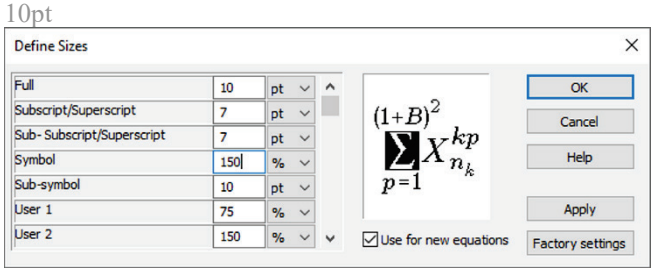

Figure 2 The texts under figures

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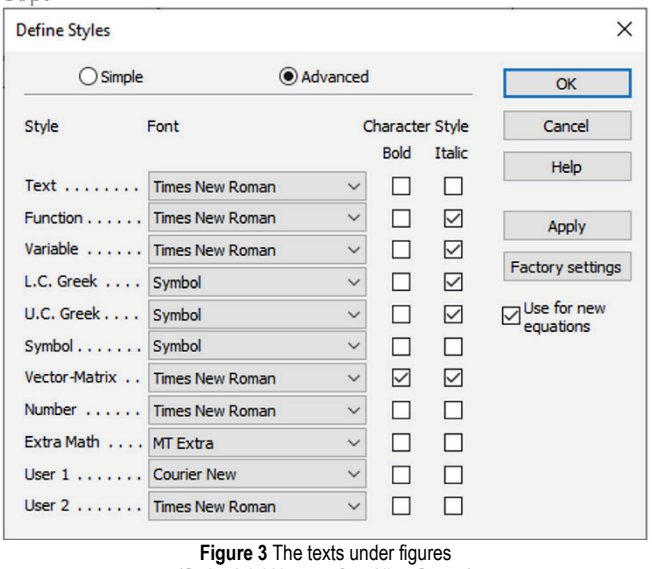

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Article that is offered for publication cannot be published beforehand, be it in the same or similar form, and it cannot be offered at the same time to a different journal. Author or authors are solely responsible for the content of the article and the authenticity of information and statements written in the article.

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Original scientific papers are articles that according to the reviewer and the editorial board contain original theoretical or practical results of research. These articles need to be written in such a way that based on the information given, the experiment can be repeated and the results described can be achieved together with the author's observations, theoretical statements or measurements.

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Conclusion is a part of the article where the results are being given and efficiency of the procedure used is emphasized. Possible procedure and domain constraints where the obtained results can be applied should be emphasized.

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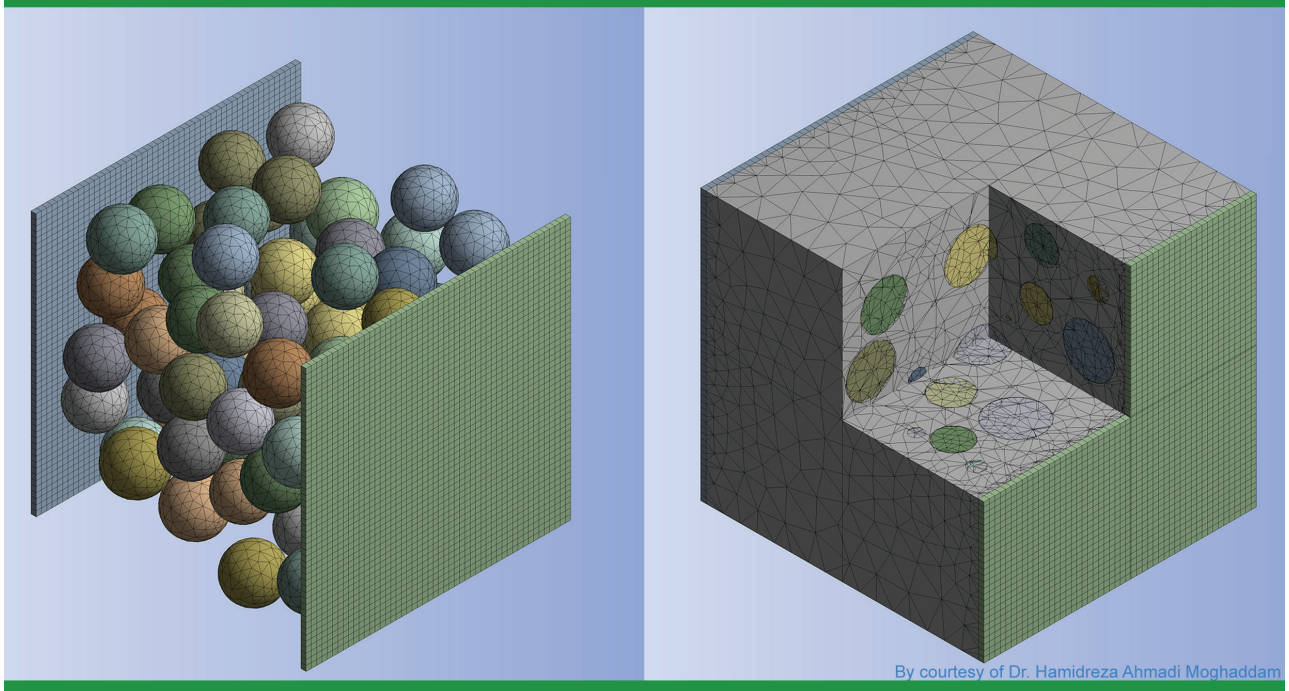

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INFORMATION FOR PARTICIPANTS

CONFERENCE VENUE
Mrs Maja Kardum
Sales department hotel Kolovare
Bože Peričića 14, 23000 Zadar
T: +385 23 203 184
T: +385 91 110 0297
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