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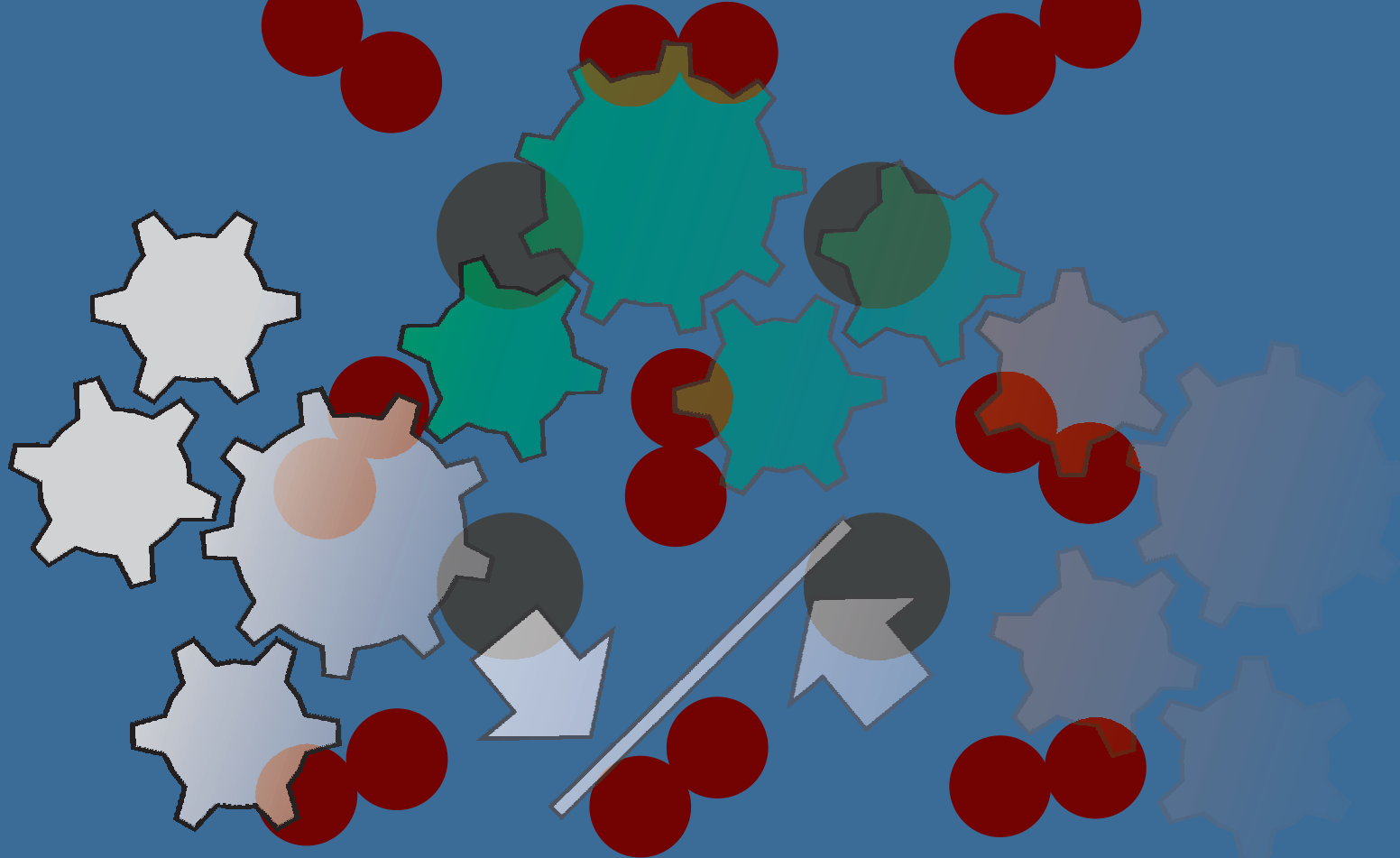

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CONTENTS
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INVESTIGATION OF THE WATER CONTENT OF CH_4-H_2 SYSTEM

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Keywords: hydrogen, water content, water dew point, methane-hydrogen mixture, renewable energy
Abstract: Hydrogen, as the clean energy carrier of the future can play a significant role in climate policy efforts in the near future. The study National Energy Strategy 2030 published in January 2020 defines the natural gas network as a seasonal energy storage. Several European countries have investigated whether hydrogen predominantly from renewable sources can be introduced to the natural gas system to reduce GHG emission. One of the important parameters of the natural gas fed into the gas network is the water vapor content, its maximum value of which is regulated by law. In this article, the authors examined whether hydrogen, which differs significantly from the properties of methane, causes a significant change in water saturation. The investigated pressure and temperature ranges cover every state found in the processing and transportation of natural gas. To carry out the calculations the Aspen HYSYS program was used.

1 Introduction

The European Commission's "Hydrogen Strategy for a Climate-Neutral Europe" was published in July 2020, which highlights key priority of hydrogen in achieving the EU's 2050 decarbonization targets [1]. Hydrogen is expected to play a significant role in bridging the current gaps in renewable energy storage and, in addition to reducing greenhouse gas emissions by producing water vapor only when combusted, will also offset seasonal fluctuations in energy needs. According to the communication the hydrogen could be a substitute for fossil fuels and increase the global competitiveness of industries with significant CO_2 emissions. It can also offer an opportunity to reduce GHG emissions in the transport sector. Hydrogen can be produced using electrolysis from electricity which thus can be stored for a longer time period, regardless of the seasonal and periodic fluctuations in the demand for natural gas. The study also mentions the existing natural gas infrastructure as a storage facility for hydrogen produced on a renewable basis, but the basis of the natural gas network use is to make the elements of the existing network technically suitable for continuous contact with hydrogen [2].

The growing interest in hydrogen is underpinned by "A Clean Planet for All" published in November 2018, which sets out the EU's climate-neutral strategic vision that the current share of hydrogen will increase to 14% by 2050 within Europe's energy mix [3]. The advancement of pure hydrogen could help the European Union achieve its goal of reducing GHG emissions by at least 40% by 2030 compared to 1990 levels [4].

Hydrogen differs significantly in its physical and combustion characteristics from methane. Therefore, it is necessary to examine how the parameters that must be met with the public service gas quality standards will change when a hydrogen is mixed with methane. In this paper, the authors refrain from reviewing all parameters influenced by hydrogen, examining only one important characteristic, the change in water saturation as a function of pressure, temperature and hydrogen content.

2 Importance of water dew point of natural gas

The water content of the produced natural gas is determined by the reservoir properties. The significant part of the undesired water content is separated during the treating process of the natural gas to set the water dew point before transfer to the natural gas network.

The risk of water content dissolved in natural gas is that water vapor may condense during transport due to pressure and/or temperature drop and can accumulate at the bottom of the pipeline, reducing the flowing cross-section in either liquid or solid state. In addition, water is corrosive to metals, which is amplified in the presence of CO_2 and H_2S content. The water content present in the natural gas also has a negative effect on the structural elements of the

INVESTIGATION OF THE WATER CONTENT OF CH4-H2 SYSTEM
Anna Bella Galyas; László Kis; István Szunyog; László Tihanyi

pipeline and on the associated consumer equipment. For this reason, the dew point of the natural gas is set to prevent water condensation.

Gases reach a saturated water content when the partial pressure of the water vapor dissolved in them is equal to the equilibrium vapor pressure of the water at a given temperature. As the temperature of the saturated gas decreases, the precipitation of water dissolved in it begins. The dew point of natural gases is thus the temperature at which the partial pressure corresponding to the water vapor is equal to its vapor pressure. The dew point temperature depends significantly on the pressure; at the same humidity it increases with increasing pressure. A given dew point temperature value has a lower absolute humidity at higher pressures [5,6].

After the water dew point setting, the gas in the domestic natural gas supply system can be considered practically dry gas, because water condensation is not happening at the transport and distribution pressures and corresponding temperatures. In Hungarian practice, the supplied natural gas may contain a maximum of 0.17 g/Nm^3 of water vapor. The standard established by CEN specifies a dew point temperature of -8 °C at the maximum operating pressure, which is stricter than the European average, as it means a maximum water vapor content of 65 mg/Nm^3 at 70 bar (a) [7,8].

3 Introduction of the model used in the investigation of water content

The effect of hydrogen mixed with methane, the main constituent of natural gas, on water saturation was investigated using the simulation software Aspen HYSYS. The equation of state used for the model tests was selected by comparing the water saturation values at different temperatures provided by different models with the data obtained from a laboratory measurement, as illustrated in Figure 1 [9].

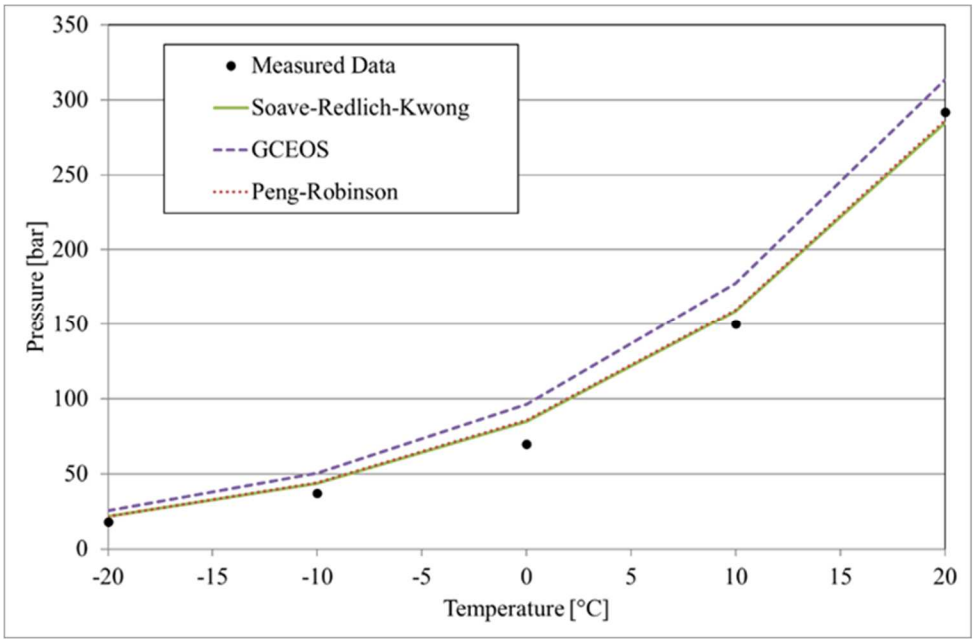

Figure 1 Selection of the equation of state used in the modelling procedure

Figure 1 shows the curves closest to the points generated during the measurement, calculated using different equations of state. Based on a comparison of the measured and software-calculated data, the most widely used Peng-Robinson equation for real gases was used in the model testing for water saturation.

To analyse the effect of the hydrogen content in the methane-hydrogen system on water saturation, the water saturation of 100 V/V% H_2 at different pressures and temperatures was determined. The simulation was performed in the temperature range of (-20)-60 °C and pressure range of 0-70 barg, its graphical representation is shown in Figure 2.

Based on the looking at the hydrogen saturation curves, it can be stated that the highest water content occurs at atmospheric pressure and at 60 °C. The water content dissolved in hydrogen increases with increasing temperature until it decreases with increasing pressure, as a result of which the lowest water saturation occurred in the test range at an overpressure of 70 bar and -20 °C.

The HYSYS model constructed for the water saturation change study under the action of hydrogen mixed with methane is shown in Figure 3.

In the model, hydrogen is mixed with methane through a manifold. The methane-hydrogen gas mixture is then fed to a saturator where it is saturated with water vapor at a

given pressure and temperature, i.e. it reaches the maximum water content so that no liquid phase develops.

During the simulation, methane and hydrogen introduced to the manifold have the same pressure and temperature. The tests were performed for a gas mixture with 0-100 V/V% hydrogen content, where the test pressure range was 0-70 barg, using 10 bar increments, for which the water saturation values were determined in the (-20)-60 °C temperature range with 10 °C step size.

The objective of the ADJ-1 element placed in the model is to keep the resulting gas mixture at constant volumetric flow rate. As the hydrogen content in the gas mixture increases, the volume flow of methane decreases accordingly. The ADJ-2 element is responsible for keeping the pressure of methane and hydrogen, while the ADJ-3 element is responsible for keeping its temperature constant. The ADJ-4 element eliminates the effect of temperature changes due to the mixing of real gases.

4 Water content investigation of CH_4-H_2 systems

During the simulation studies, an increasing volume of hydrogen was added to the methane in order to create clear conclusions about its effect on the maximum water saturation.

Figure 4 shows the case in which the hydrogen content is 10 V/V% of the gas mixture, showing the difference in water saturation relative to pure methane. It can be observed that the most significant deviation occurs at the lowest test temperature value, i.e. -20 °C. It can also be observed that as the temperature increases, the deviation from pure methane shows a decreasing trend. In terms of pressures, the most significant difference occurs at a pressure of 40 barg at -20 °C, in this case the amount of saturated water vapor soluble at the given physical state increases by 3.5% compared to the water saturation of 100% CH_4. It can also be observed that at this temperature and at a higher pressure there is a decrease in the saturated water vapor content of pure methane, so that approximately a difference of 2% occurs in the presence of 10 V/V% hydrogen. At 60 °C and in the pressure range of 10-70 barg, there is a 0.2-1.2% difference in the saturated water vapor content compared to the pure methane.

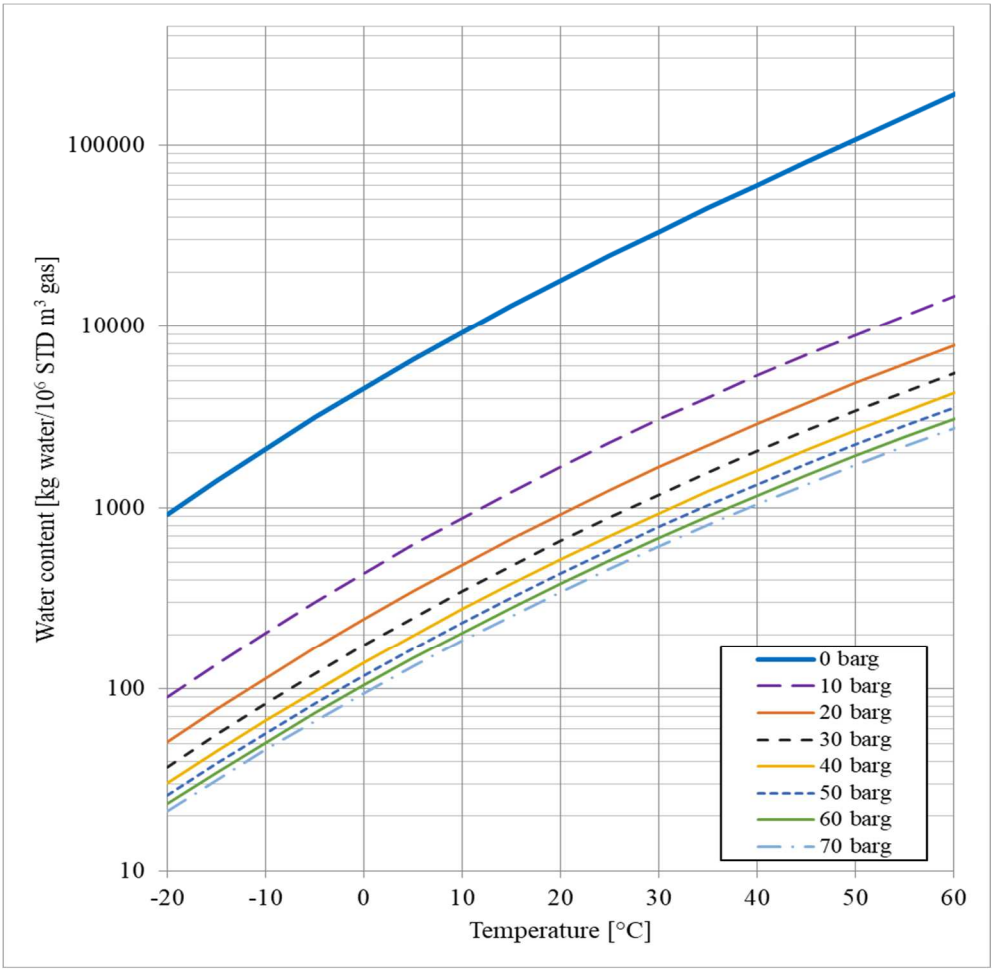

Figure 2 Change in water saturation of pure hydrogen as a function of pressure and temperature

INVESTIGATION OF THE WATER CONTENT OF CH4-H2 SYSTEM
Anna Bella Galyas; László Kis; István Szunyog; László Tihanyi

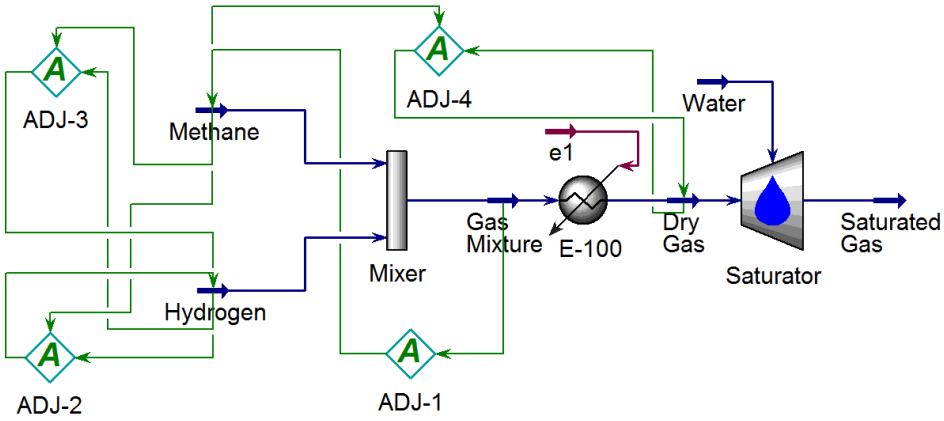

Figure 3 Structure of the model used for simulation studies

Tests were performed at every 10 bar pressure stage, but the presentation of the results is limited. For this reason, the Figure 5 shows the change in water saturation for 100% hydrogen relative to the saturated water vapor for pure methane. Based on Figure 5, the change in saturated water content shows a similar trend as in the case of 10 V/V% hydrogen content. The largest deviation occurs at the lowest temperature tested at a pressure of 40 barg, where the deviation is close to 5%. It can also be said that with increasing temperature, a nearly linearly decreasing trend is observed in the change relative to the water saturation of pure methane gas.

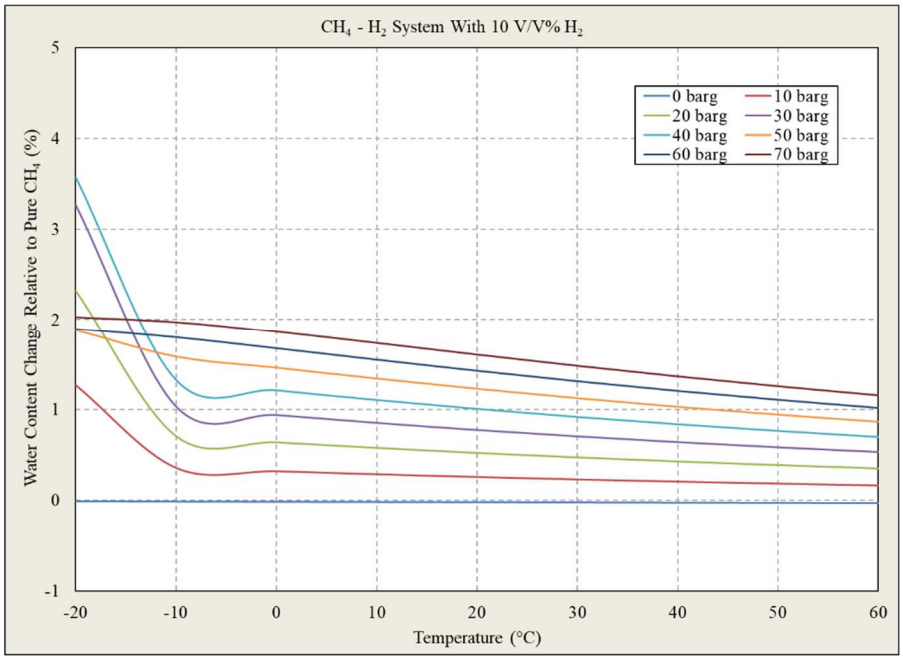

Figure 4 Water content change in case of 10% H_2 in the gas mixture

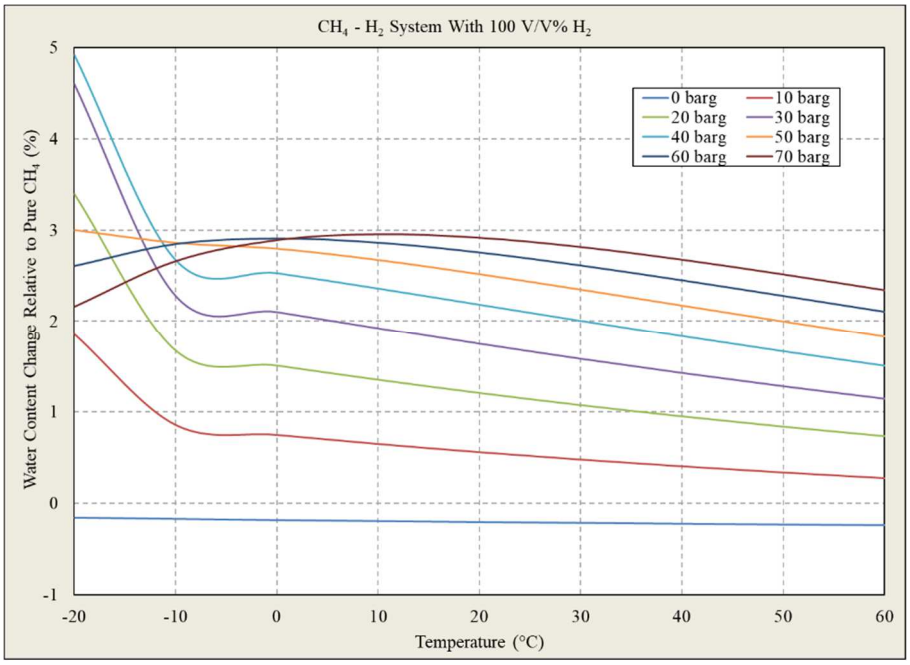

Figure 5 Maximum water content of hydrogen compared to pure methane

We also extended our investigation to see how the saturated water vapor content of the methane-hydrogen system changes compared to pure methane at constant temperatures for different hydrogen concentrations, the results of which are illustrated in Figures 6 and 7.

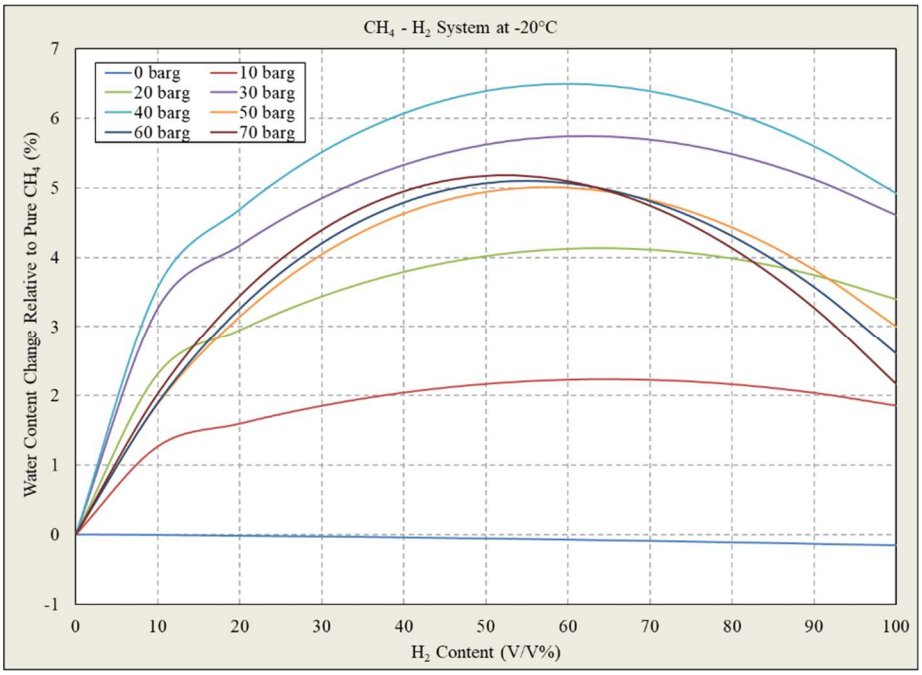

Figure 6 Water content change at -20 °C

It can be seen that the most significant change occurs at approx. 60 V/V% hydrogen content, which is increasing by a decrease in temperature. Until 60 V/V% hydrogen content, a strong upward trend can be observed for the change in saturated water vapor content at every investigated temperature, and then with a further increase in hydrogen content, the rate of change in saturated water vapor relative to pure methane decreases consistently.

At -20 °C and 40 barg pressure a gas mixture with 60 V/V% hydrogen content, the increase is 6.5%, while at the same hydrogen content and at 10 barg pressure, there is only a 2.2% difference. With increasing pressure, it can be

INVESTIGATION OF THE WATER CONTENT OF CH4-H2 SYSTEM
Anna Bella Galyas; László Kis; István Szunyog; László Tihanyi

observed that at 70 barg the saturated water vapor content of pure hydrogen gas differs by 2.2% compared to methane gas, i.e. the increase of pressure above 40 barg shows that the change in water saturation compared to methane gas at the same temperature. At a temperature of 60 °C, which is illustrated in Figure 7, there is already a clearer picture of the change in water saturation. At this temperature, as the pressure increases, the change in saturated water vapor content increases to a hydrogen content of 60 V/V%, and then, as a further increase in H_2 content, a decrease begins until a H_2 content of 100 V/V% is reached. Based on the simulation studies, the increase in water saturation of pure hydrogen gas was only 0.3% at 10 barg and 2.3% at 70 barg.

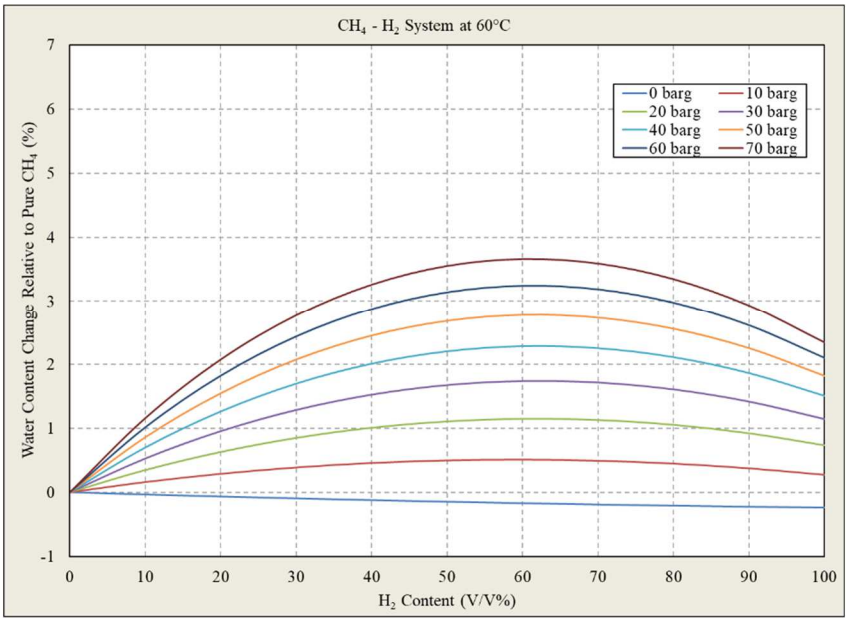

Figure 7 Water content change at 60 °C

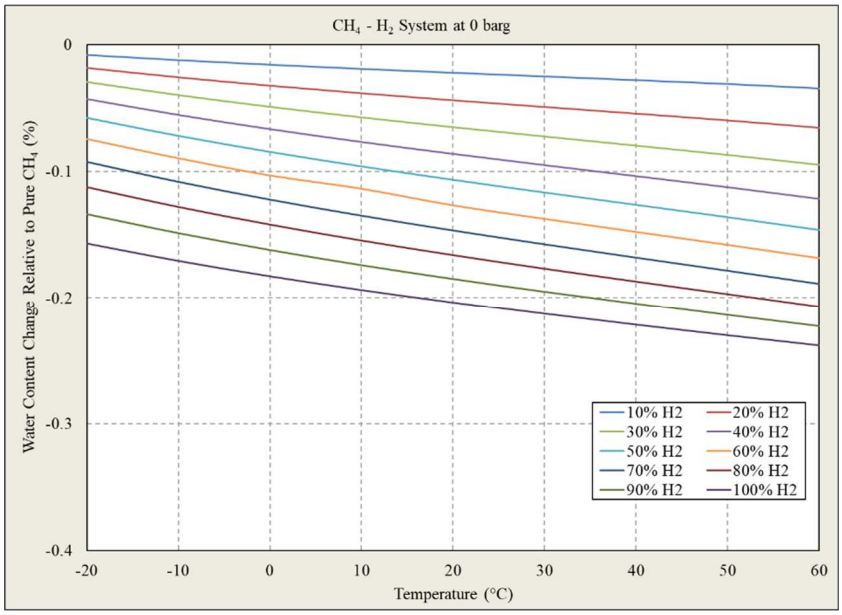

Figure 8 Water content change at 0 barg

In Figure 8 the pressure of the methane-hydrogen system is kept at atmospheric, its temperature and composition varied in the intervals introduced previously. At 0 barg pressure the changes in water content are well approximated with linear function in the investigated interval. With increasing hydrogen content, the maximum water content decreases, this effect is further enhanced with increasing temperature. The greatest change we found at 60 °C and assuming 100% hydrogen. In this case the maximum water saturation dropped by 0.23%.

The behaviour of the investigated gas mixture changes significantly with increasing pressure. Figure 9 uses data at 70 barg pressure. In this figure the relationship between the temperature and the hydrogen concentration will influence the maximum water content in a more complex way. In the lower hydrogen concentrations below 60 V/V%, an increasing hydrogen content will increase the maximal water saturation in the gas mixture. Above this concentration the water saturation will drop if more hydrogen is introduced into the mixture. This effect is valid for the temperature range investigated. The peak difference compared to pure methane occurs at -8 °C using 60 V/V% hydrogen, resulting in 5.3% water content increase relative to pure methane.

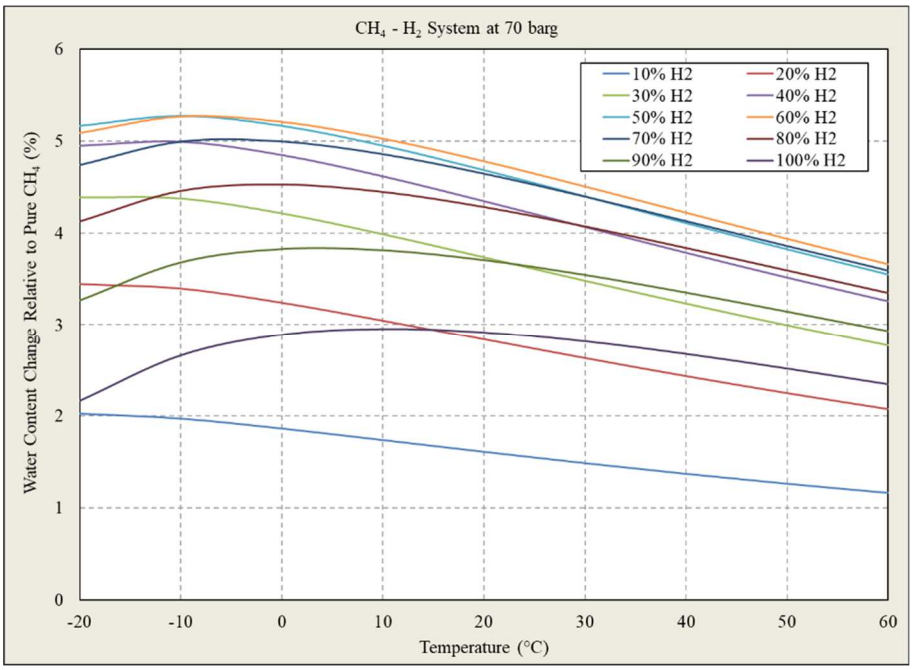

Figure 9 Water content change at 70 barg

5 Results and discussion

The authors conducted a study to determine the effect of the emergence of hydrogen as the energy carrier of the future on the natural gas network on one of the important parameters of natural gas, the dew point. The simulation was performed with Aspen HYSYS, which is widely used in the oil and gas industry. During the tests, various pressure and temperature ranges were investigated to describe the hydrogen-methane system, which represent any degree of variation in the hydrogen content of the main constituents of natural gas, the pure methane.

As a result of the tests, it can be determined that as the temperature increases, the ratio of the water saturation change of the saturated water vapor content of the methane-hydrogen system relative to the pure methane decreases. Using pure hydrogen, the most significant difference is at the lowest test temperature and 40 barg pressure, which resulted in an increase of nearly 5% relative to the saturated water content of the pure methane. In the presence of 10 V/V% hydrogen content, only a difference of 3.6% was observed under the same conditions.

It was also found that an increase in temperature reduces the change relative to pure methane. In our studies, it was found that with the same hydrogen content and with increasing pressure above 0 °C, the change in water saturation increases consistently.

When testing a methane-hydrogen system with different volume fractions of H_2, the largest difference was at 40 barg pressure and at 40 V/V% hydrogen concentration, resulting in a 6.5% change in the maximum water content compared to pure methane. A further increase in H_2 concentration content results in a decrease in the change in water saturation.

Examining the methane-hydrogen system at atmospheric pressure, it can be observed that in all cases with a volume fraction of H_2 there is a slight decrease in the saturated water vapor content compared to pure methane.

Based on the results of the simulation studies, it can be determined that the appearance of hydrogen in the natural gas network does not necessitate a technological change in the gas treating procedure of a natural gas with high methane content with regard to the setting of water dew point. This finding is valid for both current and future stricter requirements, as this amount of hydrogen content does not cause a significant difference in terms of maximum water saturation.

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THE ROLE OF SUPPLY CHAIN DYNAMIC CAPABILITIES AND SUSTAINABLE SUPPLY CHAIN MANAGEMENT PRACTICES ON SUSTAINABLE DEVELOPMENT OF EXPORT ENTERPRISES

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***Keywords*:** sustainable development, supply chain dynamic capabilities, sustainable supply chain management, sustainable enterprises

Abstract: Research on supply chain sustainability is important for exporters. Sustainable supply chain management (SSCM) as well as good use of supply chain dynamics will help enterprise adapt to changes in the business environment. This study analyzes the impact of SSCM, supply chain dynamic capabilities on the sustainable development of exporting enterprises in Vietnam. Analyzing with 185 samples, SEM structure model analysis techniques have shown that supply chain dynamic capabilities, SSCM all have positive effects on the sustainable development of businesses (sustainable development is measured by distribution: measuring economic efficiency, social efficiency, and environmental performance). From the results of this study, the authors also made a number of recommendations to help export enterprises to develop sustainably based on the factors of SSCM and supply chain dynamic capabilities.

1 Introduction

Vietnam's participation in the WTO and the opportunity to join CPTPP is not only an opportunity, but also a great challenge for companies. Especially with exporting enterprises, it is considered that they are most affected by joining the economic union. Therefore, the development of export enterprises in Vietnam plays an important role in Vietnam's economy. However, The businesses still face difficulties in developing, and managing supply chains [1]. Supply chain management has become one of the main means for companies to control costs, and improve economic efficiency in the face of increasingly competitive markets [1,2].

Hanifan et al found that by setting the enterprise supply chain, not only to cut costs and improve risk management, but also create new sources of income and increase brand value [3]. In effective supply chain implementation, supply chain dynamics, and supply chain capacity play an important role in increasing competitiveness and firm's performance [4]. With the traditional supply chain capabilities, tangible resources (products, technology) are becoming familiar to all companies. Supply chain resources are easy to spot and evaluate, so they are easy to catch first, leading to a loss of value due to their popularity and visibility.

Besides, existing in the enterprise intangible resources (knowledge, leadership art) is difficult to detect and imitate [1]. That is the source of enterprise dynamics [5]. With the development of science and technology, products launched with shorter life cycles have led to businesses needing continuous product innovation [1]. At the same time, tangible changes or supply chain capabilities are easily duplicated. Therefore, dynamic factors become more necessary to create competitive advantage and bring enterprises efficiency[1,6]. Therefore, enterprises must always make efforts to identify, nurture develop and use dynamic competencies effectively and adapt to changes of business environment.

Many studies have been conducted to evaluate the supply chain, and enterprises performance. In particular, Liao et al (2018) conducted an assessment of the impact of supply chain capacity on competitive advantages for manufacturing enterprises; Hong et al. (2018) study the impact of supply chain dynamics, supply chain management practices on the development of businesses; Zott (2003), Griffith et al. (2006) and Eriksson (2014) both studies that the impact of supply chain dynamics has a positive impact on enterprises performance [7,8]. Although studies in the world are carried out on the above issues, in the environment of Vietnamese enterprises, according to the author's study, there has not been any study to assess the supply chain dynamics, sustainable supply chain management practices and the sustainable development of the enterprises. Therefore, the author assesses the role of supply chain

THE ROLE OF SUPPLY CHAIN DYNAMIC CAPABILITIES AND SUSTAINABLE SUPPLY CHAIN MANAGEMENT PRACTICES ON SUSTAINABLE DEVELOPMENT OF EXPORT ENTERPRISES

Hoi Van Nguyen; Tha Hien To; Viet Xuan Trinh; Duong Quy Dang

dynamics, sustainable supply chain management practices to the sustainable development of export enterprises.

2. Literature review

2.1 Sustainable supply chain management practices

Sustainable supply chain management (SSCM) is a supply chain management (SCM) focused on environmental, economic and social protection issues for long-term sustainable enterprises development [9-12]. SSCM is the management of input materials, capital issues, cooperation between companies in supply chain operations to achieve sustainable development goals (economic, social and environmental) (Seuring & Müller, 2008). SSCM can be divided into two main categories: SSCM as a management philosophy & SSCM as a set of management processes [10]. SCM's activities in addition to bringing about economic benefits for businesses, creating jobs for workers, need to make sure that the whole society is concerned about the environment [10,13].

SSCM practices in enterprises are the implementation of SCM measures inside and outside the enterprise to achieve three sustainable development goals [14]. SSCM practics is divided into five components: strategic orientation, collaboration, supply chain continuity, risk management and pro-activity for sustainability [9]. Some studies have divided SSCM practices into other aspects: incorporating sustainable product design, process design, and sustainability collaboration with suppliers as well as customers [14]. In addition, there are also researches on SSCM practices into 4 elements: sustainable production, sustainable design, Sustainable distribution and return on investment [15]. It can be seen that there are different results of SSCM practices in each field or research environment. The main components of SSCM practices in the environment of export enterprises in Vietnam.

2.2 Supply chain capacity

Supply chain capacity is the construction of a closed cycle of supply chain strategy to help supply chain development as well as enterprises development [16]. Supply chain capacity can be divided into several aspects: the ability to handle supply-oriented processing and the ability to create value-added value according to demand. Supply-driven processing capabilities that use standardized and standardized supply chain business processes for extensive, in-depth analysis, distribution to create a more efficient delivery of products and services and reduce total costs [1]. The ability to create value-added on demand to meet customer needs for special products or customized services, designed to create value-added customers and maximize customer satisfaction customers and continuous improvement.

2.3 Supply chain dynamic capacity

Supply chain dynamic capacity is built on general dynamics and applications in supply chain operations [1]. Supply chain dynamic capacity is a new concept in Vietnam and is considered a complex process [9]. Supply chain dynamics is the supply chain capability that can cope with changes in the enterprises environment [1]. Dynamic supply chain dynamics help organizations to be more creative, more flexible with business situations [17].

3. Method

3.1 Research model

The framework for selection theory research is Hong et al. (2018); Esfahbodi et al. (2016) and Suhaiza et al. (2012) with the impact of supply chain dynamic capacity, Sustainable supply chain management on sustainable development of export enterprises. The author's research model is as follows (Figure 1).

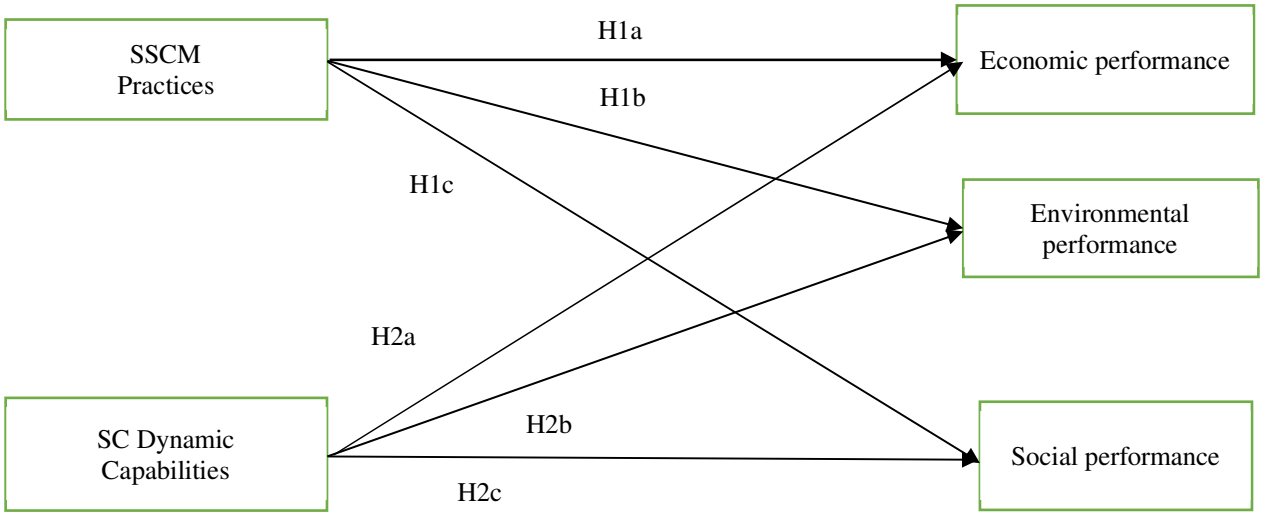

Figure 1: Proposal model

Hypothesis:

SSCM practices can enhance the enterprises results when activities in the purchase of environmentally friendly materials, or how sustainable products have a positive impact on economic and social enterprises [18]. Also, according to Wang and Sarkis (2013), SSCM practices have a positive effect on financial performance through ROE (return on equity) and ROA (return on assets), and this effect can last up to 2 years [19]. In addition, several studies have shown that the green supply chain has a positive effect environmental performance, economic performance, social and operational performance [20]

Therefore, the research hypothesis is given as follows:

H1a: SSCM practice has a positive impact on economic performance.

H1b: SSCM practice has a positive impact on environmental performance.

H1c: SSCM practice has a positive impact on social performance.

Zott (2003), Griffith et al. (2006) and Eriksson (2013) confirm that dynamic capacity allows a company to gain competitive advantage and thus improve the efficiency of enterprises. Menguc and Barker (2005) find similar results for the dynamics of economic performance. In addition, enterprises with good motivations show the ability to acquire knowledge as well as knowledge of good society. This will make enterprises more aware of social or environmental issues. Business ethics is also highly appreciated by the community for businesses operating not only for economic purposes but also for social and environmental goals. This will make the business more sustainable. Therefore the theory is published as follows:

H2a: SC dynamic capabilities has a positive impact on economic performance.

H2b: SC dynamic capabilities has a positive impact on environmental performance.

H2c: SC dynamic capabilities has a positive impact on social performance.

3.2 Design and sample

The author used the scale of Hong et al (2018) and Liao et al (2017) to build the survey with the set of scales using Likert 5 points with point 1 – disagree strongly and 5 agree strongly, the survey is summarized in the following table 1.

Table 1 Survey

Code	Content	Reference
I	***Supply chain dynamic capacity***	
SCDC1	Enterprises are capable of acquiring knowledge about supply chains	Hong et al (2018)
SCDC2	Enterprises are aware of market-oriented supply chains	
SCDC3	Enterprises with supply chain creativity	
SCDC4	Enterprises have the ability to re-establish supply chains	
II	***SSCM practics***	
SSCM1	Supply chain coordination and trust	Hong et al (2018)
SSCM2	Supply chain learning	
SSCM3	Supply chain strategic orientation	
SSCM4	Supply chain risk management	
SSCM5	Supply chain continuity	
III	***Economic performance***	
EP1	Business operations are always favorable	Hong et al (2018); Liao et al (2017
EP2	Market of large enterprises	
EP3	Enterprises are financially effective	
IV	***Environmental performance***	
ENP1	Enterprises have good control over environmental pollution	Hong et al (2018)
ENP2	Resource utilization	
V	***Social performance***	
SP1	Enterprise perspective	Hong et al (2018)

Code	Content	Reference
SP2	Employee perspective	

Source: References from previous studies

Research samples were collected with exporters in Vietnam. Forms of direct and online are based on Google Docs. The survey period is from 10/2019 to 02/2020. With the number of sample collected is 185 samples to ensure reliability for data analysis when the conditions of minimum sample size are satisfied: According to Hair et al (2006) the number of good samples is over 100 [21]; or according to Tabachnick and Fidell (2007) with the number of samples calculated as 50 + 8*p = 66 (with p = 2-independent variable) [22]. After the data was collected, the author continued to encode and put into SPSS, AMOS 20 software for analysis. The analytical techniques are detailed in the next section.

3.3. Data analysis

The sample (n = 185) will be put into the analysis and evaluation of reliability through Cronbach's Alpha coefficients, the correlation coefficient of variables with the criteria: Cronbach Alpha coefficient is greater than 0.6 and the correlation of the total variable greater than 0.3 [21], [23]; Next to exploratory factor analysis technique (KMO greater than 0.5, p-value of Bartlet test <0.05, and TVE is greater than 50%).

Next, the research uses confirmatory factor analysis and structural equation model analysis (SEM). Conformity assessment of research scale: validation factor analysis (CFA) is used to converge validity, and discriminant validity. Next, the study uses a structural equation model (SEM) at 5%. CFA models, and SEM is reliable when the conditions Chi-2 / df is less than 3. The value of CFI, TLI, IFI is greater than 0.9; RMSEA is less than 0.05.

4. Result

4.1 Reliability test

To indicate the reliability scales, Cronbach's Alpha and correlation coefficients were used in this verification step. The reliability test results show that factors of supply chain dynamic capabilities, Sustainable supply chain management practices, enterprises performance all achieve reliability (Cronbach's Alpha coefficient is greater than 0.6 and the correlation coefficient of the total variable of The items are bigger than 0.3). The results of CFA (Figure 2). show that: Chi-square / df = 1,842 is less than 3, CFI = 0.914; TLI = 0.902; IFI = 0.915 are greater than 0.9, RMSEA = 0.051 is less than 0.08. This shows that the theoretical model is compatible with market data. The factor load factor is greater than 0.5, the composite reliability of the factors above 0.7 and the Average Variance Extracted (AVE) are greater than 50% compared to see the model of convergence validity (Table 2).

Table 2 Reliability test

		Factor	λ	Composite Reliability	AVE (%)	Cronbach's Alpha
SCDC2	<---	SCDC	0.641	0.819	0.730	0.816
SCDC1	<---	SCDC	0.768			
SCDC4	<---	SCDC	0.809			
SCDC3	<---	SCDC	0.693			
SP2	<---	SP	0.939	0.873	0.881	0.869
SP1	<---	SP	0.819			
EP1	<---	EP	0.862	0.902	0.869	0.903
EP3	<---	EP	0.837			
EP2	<---	EP	0.908			
SSCM3	<---	SSCM	0.663	0.840	0.718	0.848
SSCM2	<---	SSCM	0.801			
SSCM1	<---	SSCM	0.619			
SSCM5	<---	SSCM	0.734			
SSCM4	<---	SSCM	0.76			
ENP2	<---	ENP	0.794	0.873	0.881	0.865
ENP1	<---	ENP	0.961			

THE ROLE OF SUPPLY CHAIN DYNAMIC CAPABILITIES AND SUSTAINABLE SUPPLY CHAIN MANAGEMENT PRACTICES ON SUSTAINABLE DEVELOPMENT OF EXPORT ENTERPRISES

Hoi Van Nguyen; Tha Hien To; Viet Xuan Trinh; Duong Quy Dang

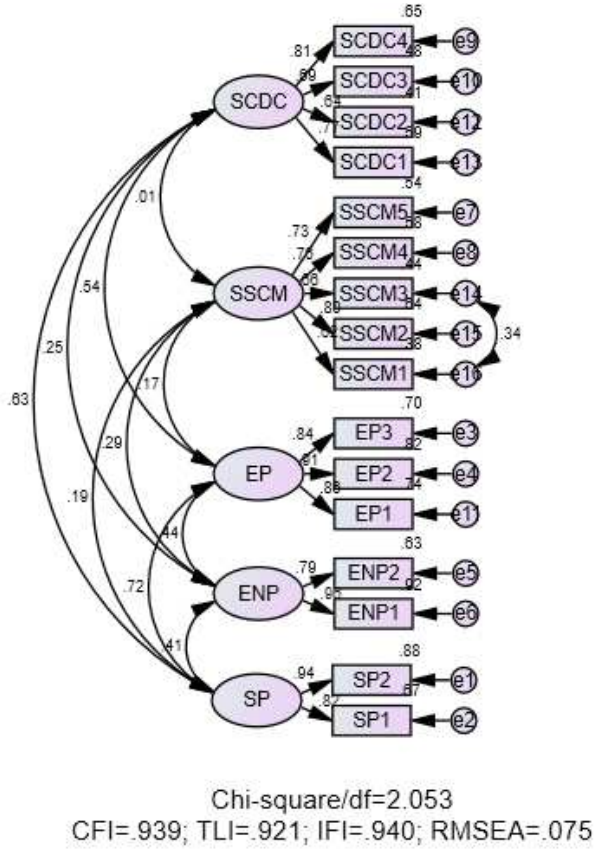

Figure 2 Result of CFA

Factor loading greater than 0.5 in each factor are considered to have convergence validity and the square root of the AVE greater than the correlation between research concepts are concepts with discriminant validity (Table 3).

4.2 Result of SEM

After the CFA model gains aggregate reliability as well as discriminant validity. The structure model will be implemented to find out the effect of supply chain dynamic capabilities, Sustainable supply chain management practices on enterprises performance. The results of the analysis of the structural model are reliable with Chi-square / df = 2.133 is less than 3, CFI = 0.933; TLI = 0.915, IFI = 0.934 is greater than 0.9, RMSEA) = 0.078 less than 0.08.

The analysis of the structural model all indicates that the SCDC, SSCM-sustainable supply chain management practices all have the same effect on the sustainable development of exporting enterprises (p-value is less than 0.05 and the beta is positive). Through standardized beta, SEM model also shows that SCDC has a stronger impact on economic performance than SSCM (SCDC standardized beta is 0.73, while SSCM's standard beta is only 0.18). For Environmental performance most strongly affected by SCDC (standardized beta is 0.40), SSCM has a weaker impact on Environmental performance than SCDC (standardized beta is 0.30). Finally, the Social performance factor was also influenced more strongly by SCDC (standardized beta is 0.78) while SSCM's standardized beta is only 0.21. Detailed statistics are in table 4.

Table 3 Discriminant validity

	SP	EP	ENP	SSCM	SCDC
SP	**0.939**				
EP	0.717	**0.932**			
ENP	0.411	0.436	**0.939**		
SSCM	0.187	0.169	0.294	**0.848**	
SCDC	0.634	0.54	0.252	0.01	**0.855**

Source: Results from AMOS software

Table 4 Result of SEM

Regression Weights			beta	S.E.	C.R.	P-value
EP	<---	SCDC	0.730	0.132	7.685	0.000
ENP	<---	SCDC	0.404	0.170	4.280	0.000
SP	<---	SCDC	0.783	0.118	8.477	0.000
EP	<---	SSCM	0.182	0.064	2.657	0.008
ENP	<---	SSCM	0.304	0.103	3.560	0.000
SP	<---	SSCM	0.214	0.056	3.246	0.001

Source: Results from AMOS software

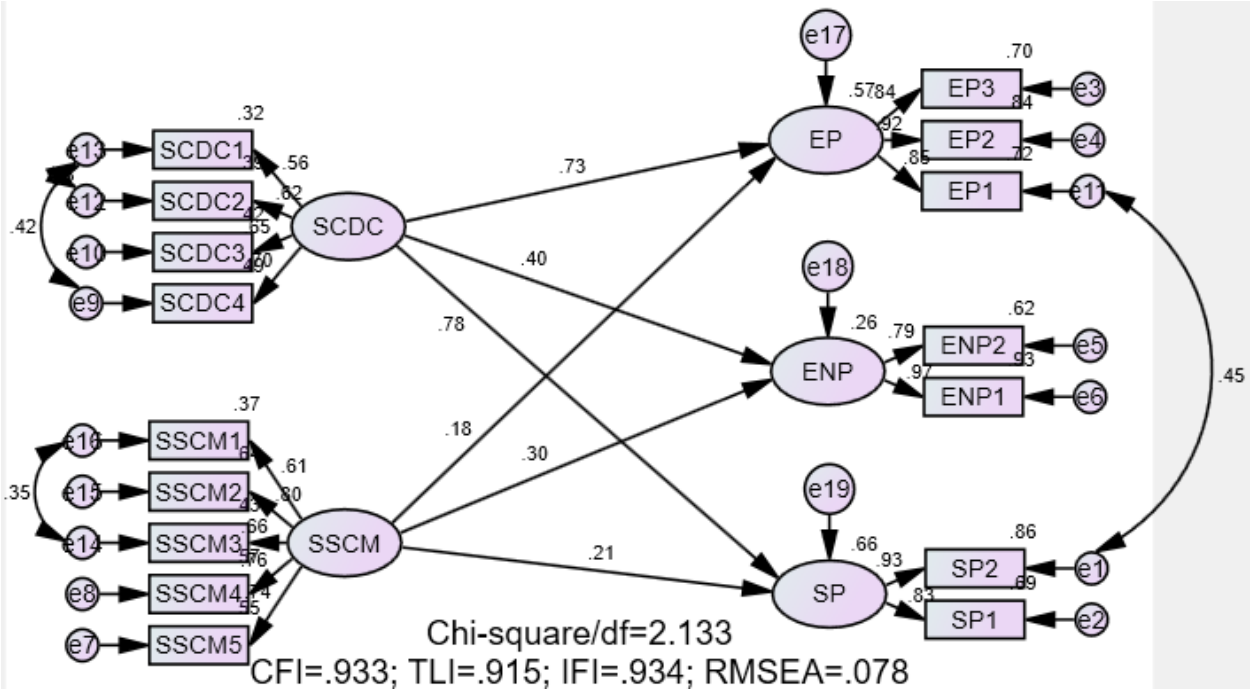

Figure 3 Result of SEM

Supply chain dynamics positively affects economic performance, which indicates that enterprises prepared supply chain dynamics well will promote economic performance. The ability of enterprises to acquire good knowledge about the supply chain helps the process activities as well as standards be maintained in a sustainable manner. New standards or processes are adopted and updated by businesses that help improve enterprises performance and bring economic value to businesses [2]. In addition to receiving knowledge about the supply chain, the higher the ability of businesses to be creative about the supply chain, the more effective it can improve the supply chain process. This will also bring high economic benefits. At the same time, reestablishing the supply chain with new processes or facilities helps to control supply chain operations better, resources or operating time will be minimized.

Supply chain dynamics also positively affect the environmental performance. This result (Figure 3) is similar to previous studies that also showed the positive effect of supply chain dynamics on environmental performance [24]. It can be seen that enterprises have good supply chain dynamics, leading to increased environmental awareness. The issue of environmental responsibility in production and enterprises activities is paid more attention by the enterprises. Simultaneously with the integration of new technologies or new modern processes, it will improve the efficiency of production and business and reduce the costs that lead to environmental pollution. Energy-efficient production and transport processes help reduce emissions. Streamlining supply chain processes or digitization will help reduce unnecessary steps and waste resources to minimize negative impacts on the surrounding environment.

Social performance is also enhanced when the supply chain dynamics of the enterprises, with the acquisition of knowledge about the supply chain helping to interact with people more. Developing a wider and more effective supply chain makes social issues such as employment and unions better. The always use or creation of supply chain processes makes partners or competitors recognize the success of the business. This makes the social effect increase; businesses or society will consider these as learning things to apply in their production activities.

Sustainable supply chain management practices has a positive impact on economic, social and environmental efficiency in export enterprises. These results point to the importance of Sustainable supply chain management practices in enterprises. A good supply chain operation or management helps promote the overall internal strength of the business and supply chain dynamics in the industry. Good coordination of the supply chain brings smooth operational processes; costs are minimized when there are no problems in the supply chain disruptions. Therefore, economic efficiency is improved. In addition, forecasting or implementing good supply chain risk management will help businesses have a contingency plan when risks in the

supply chain occur will help businesses take initiative in production and business activities.

SSCM also has a positive impact on environmental performance, indicating that businesses with good SSCM will be more likely to use energy-efficient as well as environmentally friendly products. At the same time, the operation and management of the supply chain in strict compliance with environmental protection regulations will help improve the efficiency of enterprises. Besides, supply chain inspection procedures also help to control the quality of products used in the supply chain. All problems that arise affecting the environment will be handled well by the business, so the effective monitoring and supervision of the supply chain.

Finally, SSCM also has a positive relationship with social performance. Better management of the supply chain, control issues during the supply chain implementation helps businesses satisfied with their operations. Businesses think that businesses are operating smoothly through well-functioning supply chains. At the same time, employees are also satisfied with the job when they are managed and cared for scientifically under effective management and supply chain link within the enterprise.

5. Conclusion

From the analysis of over 185 samples on supply chain operations and sustainable development of export enterprises. Research has shown that the positive effects of supply chain dynamics, sustainable supply chain management practices all have a positive effect on the sustainable development of enterprises (the enterprise's sustainable development is measured through three factors: economic performance, environmental performance and social performance, the authors also made some recommendations to help sustainably develop chain-based exporters: (1) Focus on using environmentally friendly products in the supply chain; (2) Work / cooperate with participating partners and supply chains with high social responsibility to ensure products in accordance with the regulations on both economic, social and environment; (3) Regularly updating new supply chain knowledge and processes; (4) Enhancing inspection and monitoring activities of the supply chain; (5) Setting up the system risk management in the supply chain.

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WHY THE QUEUING IN THE BANKING ENVIRONMENT IN THE ERA OF ELECTRONIC BANKING

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Keywords: e-banking, queuing, deposits money banks, Nigeria, cashless economy
Abstract: Managing queuing within the banking business in Nigeria has constituted major challenges whose effects have not been thoroughly examined. This study sets to investigate the continuous queuing in the Nigerian banking environment despite e-banking adoption in Nigeria. The research adopted a survey design where primary data were obtained using a structured questionnaire. Fifty (50) respondents were purposively chosen. A purposive sampling technique was used which considered banks having branches within Ladoke Akintola University of Technology and Ogbomoso town. OLS regression was used to determine the influence of electronic banking on customers queuing the factors for queuing in the banking environment amid e-banking adoption at 0.05 level of significance. Findings revealed that queue in the study area was most of the time very high in the morning, high in the afternoon and evening while at night, most time witnessed no queue. Electronic banking had a significant influence on customers' queuing in the study area. Further, Tendency to Hold Cash by banks customers (THC), Poor Internet Infrastructure (PII), Cybercrime (CC) were the major factors causing bank customer queue in the banking environment in Nigeria, followed by Inadequate of Banking Technology Management (IBTM) and E-Banking Transaction Cost (EBTC). Therefore, banks service providers should increase efforts on cashless e-banking services and ensure reliable internet service at all times. Bank customers should be made to appreciate other e-banking services than ATM and allay fear on tendency to hold cash.

1 Introduction

The competition in the Nigerian banking sector is said to be getting more intense, partly due to regulatory imperatives of universal banking and also due to customers' awareness of their rights. According to Olaniyi, (2011) bank customers have become increasingly demanding, as they require high quality, low priced, and immediate service delivery. They want additional improvement of value from their chosen banks. Service delivery in banks is personal, customers are either served immediately or join a queue if the system is busy. Banks' service delivery system is sometimes interrupted by the rowdiness of its customers and randomness of their arrival and service time. Population explosion is one of the single largest challenges faced by Nigerian deposit money banks. According to Haoa, and Yifei, (2011) the problem of bank queuing has existed for long time wherever our country or other countries whose population density is high but that the problem could not be solved completely in short time. They argued that though custom of paying needs time to be changed completely even with return on investment of ATM relatively low there is a need to focus on improving the queuing system of bank. This scenario in banks makes its customers filled up in a queue system for an orderly service performance. This situation calls for attention of

professionals and practitioners in banking sectors on how to manage the explosive population of customers to the benefit of banking system.

Queuing has always been a pervasive concern among bank customers in Nigeria but the continuous advancement in the use of the internet technology is expected to have brought a huge impact this phenomenon. The long queue is observed as results of some characteristics in queuing systems including arrival problems of customers, behavioural problems, statistical problems and operational problems. Thus, Nigerian banks invest greatly in technology in order to be able to meet up with the global banking development by improving the quality-of-service delivery among their customers and also to reduce the transactional cost of their services. The Central Bank of Nigeria (CBN Report 2019) on e-banking system in Nigeria reveals that e-payment machinery, especially the card technology is presently enjoying the highest popularity in Nigeria banking market. According to Interswitch statistic, Nigeria has 30million ATM card holders who conduct over 100 million transactions on the machines every month. Nigeria's 21 banks operate over 9,000 ATM machines across the country's 36 states and Federal Capita Territory (wwww.interswtch.com; retrieved 20 October 2019). Further Abifarin (2017) observed that while Nigerian banking halls are often filled with customers happily using their phones to text, chat, browse and shop online, most have never considered using that same device to avoid the banking hall altogether. With recent media attention on cyber security risks such as cloning and identity theft on the rise, many Nigerian customers are also deeply concerned about the security of their transactions. The reasons for the persistent queue in the bank environments both on the counter and banking environment despite deployment of ATM dispensed machines, EFPOS, mobile and web banking, were yet to be investigated which calls for the current empirical study.

In the Nigerian Deposit Money Banks, queuing remains one of the most common reasons for customer disgust. Despite technological advances such as online and mobile banking, customers still complain about their bank. Queue management systems are specially designed for banks allowing them to reduce queue lengths and increase staff productivity and operational efficiency. In recent years, the banking industry has transformed and banks are now competing for a higher share of customers' wallet through the introduction of electronic banking. This can only be achieved if banks provide exceptional service with a delightful customer experience since no customer like to wait deposit money banks must be able to provide adequate and efficient electronic banking tools to cater for customers' need. Therefore, extent to which the use of these identified e-banking tools has influenced customers' queuing pattern in Nigerian deposit money banks shall be the thrust of the current study.

Existing studies (of Agboola 2006; Ngango, Mbabazize, and Shukla, 2015; Oladejo 2016; Ayinla, 2018) have only appraised the influence of e-banking on the profitability and other performance, whereas, how these e-banking addresses the long queue in the banking sector were yet to be well explored. This created issue as to whether or not e-banking services have any effect on customers' queuing pattern in Nigerian banking system. There has continued to be long queue in the banking environments, a situation that cast aspersion on the efficiency of e-banking products. This suggests that certain forces have militated against full benefit ascribed to e-banking and needs to be empirically explored. The current study is expected to evaluate the factors that have been responsible for long and unending queue in the banking sector despite the prevailing use of e-banking services. The following specific objectives are expected to be achieved in the course of the study:

i. Examine the influence of electronic banking on customer's queuing pattern in deposit money banks of Nigeria.

ii. Evaluate the causes of queuing in the banking environment amid e-banking adoption Nigerian Deposit Money Banks.

2 Research Hypotheses

The hypotheses to be tested in the course of this study are stated in null form:

Ho_1. Electronic banking does not have significant effect on customer queuing pattern in Deposit money banks in Nigeria.

Ho_2. There is no significant difference in the effect of factors causing queue in deposit money banks.

3 Literature Review

3.1 Queuing

The term Queuing pattern is used to define a specialized mathematical theory of queues or waiting lines. Queue becomes the general phenomenon in our day to day life. When customers who demand service have to wait because of the lower number of servers available, then queues are formed. Another reason for the formation of the queue is when the facility, takes more than the prescribed time for serving the customers or unable to work efficiently. But no one like to wait for a long time to attain the services (Ndukwe, Omale, and Opanuga 2011). Queue system help service providers to reduce the traffic in the queue. Any queuing system is governed by some specific characteristics such as the type of queues, arrival pattern of customer, service process, queue discipline and decision to wait in the queue (Amritpal and Williamjeet 2017; Haoa, and Yifei, (2011).

3.2 Customers' service delivery in Banks

This is the effective delivery of available service to meet customer's demand. All techniques and method by which service could reach customers at any point and in

manner required are expected to improve service delivery. Service quality is widely recognized as being a critical determinant for the success of an organization in today's competitive environment. The dynamic nature of the financial system is creating the need to focus more on the customer rather the product in order to be competitive. The sector as observed by Auka, Bosire, and Matern, (2013), has been characterized by the emergence of new forms of banking channels such as Internet banking, Automated Teller Machines (ATM), phone banking, maturing financial market and global competition that are forcing bankers to explore the importance of customer loyalty and maintaining lasting relationships with customers. Banks management needs to develop strategies that will differentiate them from their competitors.Electronic Banking System is seen to be an innovative service delivery mode that offers diversified financial services like cash withdrawal, funds transfer, cash deposits, payment of utility and credit card bills, cheque book requests, and other financial enquiries, (Onyedimekwu & Oruan, 2013). These services can either be provided by the banks having physical offices or by creating a website and providing services through that or services can be provisioned through a virtual bank as well (Parasuraman, .Zeithlaml, & berry, 2002)

3.3 Challenges of Electronic Banking Adoption in Nigeria Deposit Money Banks

Various barriers to effective implementation of e-banking initiatives have been identified in the literature. Some of these problems are infrastructural deficiency such as erratic power supply and communication link especially in developing countries (Lamikanra, 2012; Ayodele, 2015). Others are Inadequate skilled managers and requisite tools on end users and client systems, large accumulation of cash in the economy, high charge or cost for the e-payment terminals (ATMs) (Littler, 2006), Non-provision of adequate security for fraud prevention, Lack of government support for the improvement of e-banking. Findings from the study of Josiah, (2015) revealed that gender, tribe, age, education level, area of residence, internet literacy and e-banking awareness had significant effects in influencing user adoption of e-banking while income level sector of employment and method of payment had no significant effect on customer adoption of e-banking in Nigeria. Other challenges according to Woherem (2000), Ovia (2005), Oladejo. (2016) and Ololade, and Ogbeide, (2017) include:

i. Tendency to hold cash and fear of technology.
ii. Power Failure and Communication Link.
iii. Lack of Computer Bank Up.
iv. Lack of Adequate Investment Capital.
v. Reduces Employment in the Country.
vi. High Charges on Machines.
vii. Loss of Confidence by the people.
viii. Cybercrimes.

3.4 Empirical Review

Literatures have produced mixed results on e-banking impact. For example, Oladejo, (2016) investigated the influence of E-payments adoption on Customers' service delivery in Nigerian Deposits Money Banks using Panel logistic Regression and concluded that when bank adopt e-payment systems, their performance level measured by customer deposits changes. Also, Ololade, and Ogbeide, (2017) conducted a research into the Issues and Challenges in E- Banking in Nigeria using survey and descriptive research designs. The study findings indicate that employees' job security has a positive relationship with E-banking and significantly influence E-banking in Nigeria. Further, Adewoye, (2013), studied the impact of Mobile Banking on Service Delivery in the Nigerian Commercial Banks. The results of the findings shows that Mobile banking improves banks service delivery and recuperate customer's relationship and satisfaction.

Wallace, Asare-Darko, and Odilon (2011) studied the modeling and analysis of queuing system in banks by using Multiple Channel, Single line queuing model. The results of the analysis of queuing systems revealed that increasing number of teller points will reduce waiting line by customers. Further, Odewole (2016) applied poisson distribution, exponential service time distribution and first come first serve (FIFO) to evaluate the effectiveness of technology at reducing queuing in Nigerian banks. The results revealed that technology influenced effective delivery system and reduces waiting line of customers in Nigerian Banks. The main conclusions of the World Cash Report 2018 are that Cash remains the most widely used payment instrument in the world and on all continents and Africa appears most reliant on cash. Available diary surveys (from 24 countries) show that in 18 countries (75%) cash represents more than 50% of all payment transactions. Further as observed by Abifarin (2017) Nigeria is estimated to have more than 148 million mobile telephone subscribers and at least 92 million of them access internet data services on their devices and that 77 percent of Nigeria's banking customers now use social media for personal purposes. He argued that Nigeria's banks have largely failed to translate this passion for the internet and social media into increased adoption of internet and mobile banking solutions. In his submissions, only 42 percent of Nigerian banking customers said they use online banking platforms for one or more banking activities, 40 percent said they have interacted with their bank using social media in the past (KPMG Reports 2015; 2018).

Haoa, and Yifei, (2011) focused on improving the queuing system of bank based on BPR. Firstly, the bottleneck problems of bank queuing are analysed as well as the concept, classification and methodologies of BPR (Business Process Reengineering). Secondly, the bank businesses are investigated and analysed. Thirdly, the queuing system of certain bank is optimized based on BPR by enterprise dynamic simulation. The problem of queuing which is related to many aspects like the customer

satisfaction is one of the most serious problems needing improved. This study uses simulation to determine the appropriate number of servers in certain period and improves the key point of the queuing system. Finally, this study proposes reasonable method of optimize the bank queuing system by using BPR. In another dimension, the CBN Reports (2019) put ATM as the most used e-payment system in Nigeria with volume of transactions at 875,519,307 as showed by the Industry e-payment figures released for half-year 2019 in Table 1 below. It had been on the increase from 375,513,154 in 2012. The implication is that of all other sources of e-payments Nigerians have favoured the use of ATM most thus buttressing the observed tendency to hold cash and fear of technology as submitted by Ovia (2005, Ayo et al 2007).

The construct of this study is embedded on Socio-Technical Systems Theory of Information and Technology Acceptance. This is based on the fact that socio-technical systems perspective has become influential in the analysis of the organizational impact of information technology. The theory views any organization as an open system of interdependent sub-units transforming inputs to desired outputs. The gainful employment of any technology hinges on the ability and willingness of users to employ it for worthwhile tasks (i.e., those deemed central to the organization's goals). Socio-technical systems theory has given birth to a framework for technology design that emphasizes holistic job satisfaction (rather than just task performance) and user participation throughout the development process. Thus, socio-technical theorists recommend the analysis of all stakeholders, not just the direct users of a technology, the formation of planning groups to oversee the design, the performance of prototyping exercises, and the analysis of likely impact the technology will have on the organization. In studying technology acceptance, socio-technical theorists conceptualize acceptance in terms of two competing forces to include control and enhancement.

Table 1 Volume of e-payment channels from 2012 to 2018

ANALYSIS OF VOLUME OF E-PAYMENT CHANNELS FROM 2012 TO 2018							
	2018	**2017**	**2016**	**2015**	**2014**	**2013**	**2012**
Cheques	9,019,278	10,808,983	11,719,847	13,466,461	15,283,933	14,211,078	12,161,694
NEFT	26,760,852	31,034,624	29,754,182	28,935,605	29,690,765	29,834,317	28,941,559
ATM	875,519,307	800,549,099	590,238,934	433,695,748	400,269,140	295,416,724	375,513,154
POS	295,890,167	146,267,156	63,715,203	33,720,933	20,817,423	9,418,427	2,587,595
WEB	50,815,901	28,991,097	14,088,247	7,981,361	5,567,436	2,900,473	2,276,464
MMO	87,086,260	47,804,561	47,053,252	43,933,362	27,744,797	15,930,181	2,297,688
NIP	663,124,139	370,870,672	153,616,450	71,223,545	40,829,854	17,112,158	4,449,654
EBILLSPAY	1,053,342	905,941	1,026,886	1,208,556	593,579	557	-
REMITA	44,461,846	39,706,264	38,249,886	19,417,371	15,029,627		-
NAPS	27,384,756	11,900,008	3,965,212	936,667	-	-	-
M-CASH	229,328	77,832	-	-	-	-	-
CENTRALPAY	1,260,380	375,356	70,239	66,031	-	-	-

Source: CBN Report on E-Payment Statistics, 2019

4 Methodology

According to Central Bank of Nigeria (2018), there were twelve (12) deposit money banks in Ogbomoso Nigeria for this research study, Purposive sampling technique was adopted. Banks that have branches in Ladoke Akintola University of Technology, Ogbomoso and also in Ogbomoso town were sampled purposively. Also bank staffs that have what it takes to monitor the queue at the ATM spot were purposively chosen. The banks that were selected for this study includes United Bank for Africa Plc, Guaranty Trust Bank Plc, First Bank of Nigeria Plc, Polaris Bank Limited, Zenith bank, all in Ogbomoso, Oyo state, Nigeria. The questionnaire designed contains both open and closed questions. In an attempt to validate how reliable, the instrument of data collection, Cronbach's Alpha test was employed. The assumption in Cronbach's Alpha reliability test is that if the Cronbach's Alpha value is equal to or more than 0.7, then there is internal consistency in the instrument. Since the Cronbach's Alpha value was 0.852, as tested then the instrument of data collection was reliable. OLS regression was used to determine the influence of electronic banking on customers' queuing pattern and the factors for queuing in the banking environment amid e-banking adoption through Statistical Package for Social Sciences (SPSS Version 20.0) program.

In formulating the model for this study (1)-(7); the model used in the work is to be modified for this work. The models shall take a general form of a multiple regression model expressed as follows:

$$Y = \alpha_o + \alpha_1 X_1 + \alpha_2 X_2 + \ldots \alpha_n X_n + \mu_t \qquad (1)$$

where: Y is Queuing pattern = dependent variables, X_1-X_n are independent variables α_o is constant and α_1-α_n represents coefficient of independent variables.

Model 1:

$$Y = f(ATM,POS,MB,IB) \quad (2)$$

Explicitly, the model is specified as:

$$QP_t = \alpha o + \alpha_1 ATM_t + \alpha_2 POS + \alpha_3 MB_t + \alpha_4 IB_t + \mu_t \quad (3)$$

By Log linearizing, the model becomes:

$$LOGQP_t = \alpha o + \alpha_1 LOGATM_t + \alpha_2 LOGPOS_t + \alpha_3 LOGMB_t + \alpha_4 LOGIB_t + \mu_t \quad (4)$$

Specifying the Error Correction Model (ECM) from equation (3), the model becomes:

$$\Delta LOGQP = \alpha o + \alpha_1 \sum LOGATM_t + \alpha_2 \sum LOGPOS + \alpha_3 \sum LOGMB + \alpha_4 \sum LOGIB + \mu_t \quad (5)$$

ECM(-1) - Lagged error correction term,
ATM - Automated Teller Machine,
POS - Point of Sales,
MB - Mobile Banking,
IB - Internet Banking,
t - time subscript.

Model 2:

$$Y = f(IGS,PII, CC, IBTM, THC,EBTC) \quad (6)$$

Explicitly, the model is specified as:

$$CQS_t = \alpha o + \alpha_1 IGS_t + \alpha_2 PII + \alpha_3 CC_t + \alpha_4 IBTM_t + \alpha_5 THC_t + \alpha_6 EBTC_t + \mu_t \quad (7)$$

CQS - Customer Queue System,
IGS - Inadequate government Support Toward E-banking Dev (IGS),
PII - Poor Internet Infrastructure (PII),
CC - Cybercrime (CC),
IBTM - Inadequate of Banking Technology Management (IBTM),
THC - Tendency to Hold Cash by Banks Customers (THC),
EBTC - E-Banking Transaction Cost (EBTC),
μ_t - White noise residual /Error term in time *t*,
α_o and α - represent regression constant and regression coefficient of the variables.

5 Results and Discussion

5.1 Comparative analysis of Inter-Bank Daily Queue Pattern

The daily queue pattern for each bank sampled was presented independently for GTB, first bank, Skye bank, UBA and zenith bank respectively. It was observed that the queue pattern on Monday morning in each bank was very high, afternoon and evening were high while night usually witnessed no-queue. Tuesday queue pattern for morning afternoon evening and night follow similar pattern. Furthermore, similar queue pattern was observed for Wednesday, Thursday and Friday. Saturday and Sunday had slightly different queue pattern for all the sampled banks. Furthermore, the Comparative analysis of inter-bank queue pattern understudied affirmed the fact that the queue pattern for all the sampled banks followed similarly queue pattern (Figure 1). Thus, it was deduced that customers Queue pattern in the study area was most of the time very high in the morning, high in the afternoon and evening while at night, most time witnessed no queue.

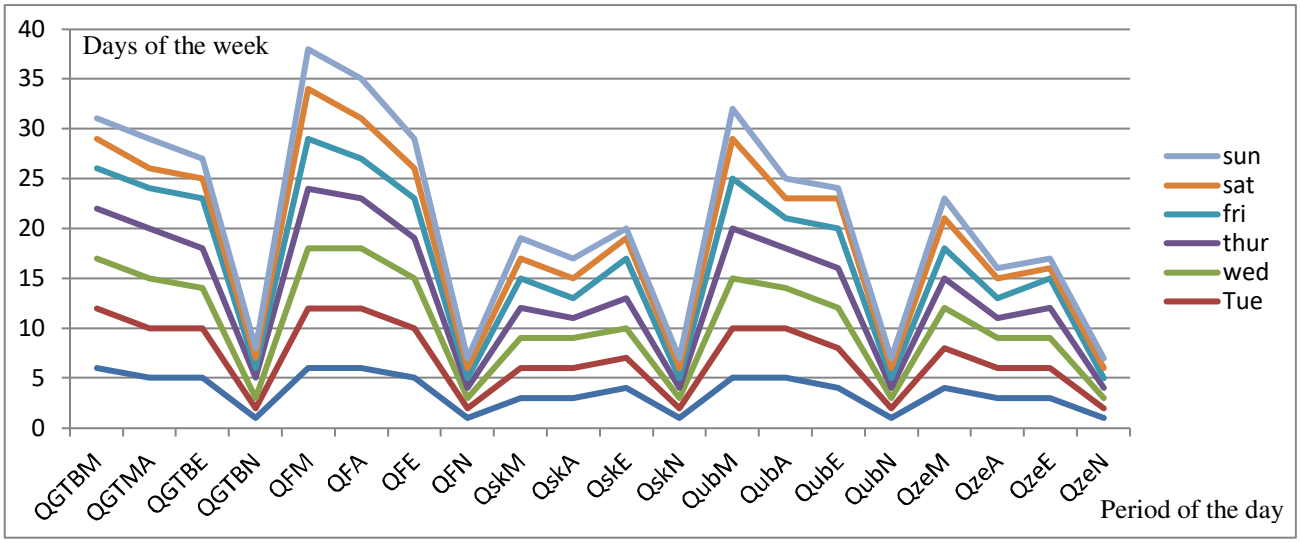

Figure 1 Comparative analysis of inter-bank queue pattern
Source: Field survey 2020

5.2 Descriptive Analysis of Electronic banking services of selected sampled deposit money banks

In an attempt to examine electronic banking services available in the sampled deposit money banks, percentage frequency was employed and presented in Table 2. The variables operationalized were E-banking service covers cash deposits service, E-banking service covers cash withdrawal service, E-banking service covers money transfer service and E-banking service covers third party transaction via ATM. It was observed all sampled respondents consented positively to E-banking service covers cash withdrawal service via ATM, E-banking service covers money transfer service via ATM and E-banking service covers third party transaction via ATM while only first bank had cash deposit service via ATM. It was deduced that all the sampled banks had cash withdrawal service, covers money transfer service and third-party transaction via ATM. While only first bank had cash deposits service via ATM.

Table 2 Electronic banking services

s/n	Variables	SD(%)	D(%)	I(%)	A(%)	SA(%)
	GTB					
1	E-banking service covers cash deposits service via ATM	6 (60.0)	4 (40.0)			
2	E-banking service covers cash withdrawal service via ATM				6 (60.0)	4 (40.0)
3	E-banking service covers money transfer service via ATM				4 (40.0)	6 (60.0)
4	E-banking service covers third party transaction via ATM				5 (50.0)	5 (50.0)
	First bank					
1	E-banking service covers cash deposits service via ATM				3 (30.0)	7 (70.0)
2	E-banking service covers cash withdrawal service via ATM				1 (10.0)	9 (90.0)
3	E-banking service covers money transfer service via ATM				3 (30.0)	7 (70.0)
4	E-banking service covers third party transaction via ATM				8 (80.0)	2 (20.0)
	Skye bank					
1	E-banking service covers cash deposits service via ATM	3 (30.0)	6 (60.0)	1 (10.0)		
2	E-banking service covers cash withdrawal service via ATM				8 (80.0)	2 (20.0)
3	E-banking service covers money transfer service via ATM				3 (30.0)	7 (70.0)
4	E-banking service covers third party transaction via ATM				4 (40.0)	6 (60.0)
	UBA					
1	E-banking service covers cash deposits service via ATM	7 (70.0)	3 (30.0)			
2	E-banking service covers cash withdrawal service via ATM				2 (80.0)	2 (20.0)
3	E-banking service covers money transfer service via ATM				3 (30.0)	7 (70.0)
4	E-banking service covers third party transaction via ATM				6 (60.0)	4 (40.0)
	Zenith bank					
1	E-banking service covers cash deposits service via ATM	4 (40.0)	6 (60.0)			
2	E-banking service covers cash withdrawal service via ATM				3 (30.0)	7 (70.0)
3	E-banking service covers money transfer service via ATM				2 (20.0)	8 (80.0)
4	E-banking service covers third party transaction via ATM				5 (50.0)	5 (50.0)
	All banks					
1	E-banking service covers cash deposits service via ATM	20 (40.0)	19 (38.0)	1 (2.0)	3 (6.0)	7 (14.0)
2	E-banking service covers cash withdrawal service via ATM				20 (40.0)	30 (60.0)
3	E-banking service covers money transfer service via ATM				15 (30.0)	35 (70.0)
4	E-banking service covers third party transaction via ATM				28 (56.0)	22 (44.0)

Source: Field survey 2020

5.3 The influence of electronic banking services on customer's queuing in banks

The influence of e-banking services on customer queuing is displayed in Table 3 and Table 4. Electronic banking services were proxy by E-banking service covers cash deposits service, E-banking service covers cash withdrawal service, E-banking service covers money transfer service and E-banking service covers third party transaction via ATM while customers' queuing pattern was proxy by Rate of queuing. It was observed in Table 4 that the coefficient of determinant R^2 was 0.382 and the multiple correlation coefficients R^2 was 0.618 implying that the extent to which predicting variables which were E-banking service covers cash deposits service, E-banking service covers cash withdrawal service, E-banking service covers money transfer service and E-banking service covers third party transaction via ATM explained the variation in the dependent variable which was Rate of queuing was 0.382.

Also, it was observed in Table 4 that E-banking service covers money transfer service had the highest effects with a beta value of 0.337, followed by E-banking service covers third party transaction via ATM with a beta value of 0.273, followed by E-banking service covers cash withdrawal service with a beta value of 0.155 and E-banking service covers cash deposits service with a beta value of -0.406. It was inferred that electronic banking had

significant influence on customers' queuing pattern in the study area. The outcome of this current study is in concomitant with the studies of Amritpal and Williamjeet (2017), Wallace, Christian &Frank (2011) that found impact of ICT and E-banking on customers satisfactions and queuing in banking environments.

Table 3 Model Summary of the influence of electronic banking on customer's queuing

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.618(a)	.382	.327	.90400

Predictors: (Constant), ESCTPTVA, ESCCWSVA, ESCCDSVA, ESCMTSVA
Source: Field survey 2020

Table 4 Coefficients of the influence of electronic banking on customer's queuing pattern

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta	B	Std. Error
1	(Constant)	-4.970	1.749		-2.841	.007
	ESCCDSVA	-.322	.102	-.406	-3.155	.003
	ESCCWSVA	.346	.329	.155	1.053	.298
	ESCMTSVA	.802	.333	.337	2.411	.020
	ESCTPTVA	.600	.263	.273	2.282	.027

Dependent Variable: WITROQIYBPW
Source: Field survey 2020

5.4 Regression Analysis on Causes of Bank customer Queue in the Era of E-Banking

Analysis in Table 5 revealed that a unit increase in inadequate government Support Toward E-banking Dev (IGS) increases customer queuing in the electronic banking environment. The analyses indicate that inadequate government Support Toward E-banking Development is significantly related to Causes of Bank customer Queue in the Era of E-Banking at 0.065 percent but not statistically significant to the cause of bank customer queue. Also a unit increase in Poor Internet Infrastructure (PII) increases Bank customer Queue by 14.9 units, which shows a positive influence between Poor Internet Infrastructure and customer queuing in the electronic banking environment Further, a unit increase in Cybercrime (CC) increases Bank customer Queue by 14.3 units. A unit in Inadequate of Banking Technology Management (IBTM) increase bank customer queuing by 8.0. More so, a unit in Tendency to Hold Cash by Banks Customers (THC) increase bank customer queuing by 15. Additionally, a unit increase in E-Banking Transaction Cost (EBTC) increases Bank customer Queue by 6.3 units. All factors except inadequate government Support were statically significant to customer queuing in the Nigerian banking environment.

Following the result of the analysis (Table 5), the coefficients of variables such as (THC- 15.52021, @0.004; PII- 14.96550, @0.000; CC-14.35838, @0.000; IBTM-8.05232, @0.000; EBTC-6.061249,) @0.003) incorporated in the model were highly significant to cause of bank customer queue in the banking environment. The result also indicate that Tendency to Hold Cash by banks customers (THC), Poor Internet Infrastructure (PII), Cybercrime (CC) were the major factors causing bank customer queue in the banking environment in Nigeria, followed by other variable like, Inadequate of Banking Technology Management (IBTM) and E- Banking Transaction Cost (EBTC).

Table 5 Regression Causes of Queue in Banks in the Era of E-Banking

Variables	**Coefficient**	**Std.Err**	**T**	**P>{T}**
Inadequate government Support Toward E-banking Dev (IGS)	3.931264	2.073144	1.90	0.065
Poor Internet Infrastructure (PII)	14.96550	1.412209	10.60	0.000
Cybercrime (CC)	14.35838	2.099307	6.84	0.000
Inadequate of Banking Technology Management (IBTM)	8.05232	2.913253	2.79	0.000
Tendency to Hold Cash by Banks Customers (THC)	15.52021	1.003264	2.50	0.004
E-Banking Transaction Cost (EBTC)	6.061249	1.928902	3.14	0.003
Constant	-38.50592	5.577238	-6.90	0.000

Source: Data Analysis, 2020
*Dependent Variable: Queue system
*R2:0.9387
*Adjusted R2 = 0.9301

6 Conclusion

Based on the findings of this study, it was concluded that queue pattern in the study area was most of the time very high in the morning, high in the afternoon and evening while at night, most time witnessed no queue. Electronic banking had significant influence on customers' queuing pattern in the study area. Further, Tendency to Hold Cash by banks customers (THC), Poor Internet Infrastructure (PII), Cybercrime (CC) were the major factors causing bank customer queue in the banking environment in Nigeria, followed by other variable like, Inadequate of Banking Technology Management (IBTM) and E-Banking Transaction Cost (EBTC). Thus, the following recommendations were made:

- Banks service providers should increase efforts on cashless e-banking services and ensure reliable internet service at all times.
- Bank customers should be made to appreciate other e-banking services than ATM and allayed fear on tendency to hold cash that could have been lost to machines.

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EFFECT OF CO_2 REACH ENVIRONMENT ON THE PETROPHYSICAL PROPERTIES OF ARTIFICIALLY CONSOLIDATED CORE SAMPLES

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Keywords: artificially consolidated, synthetic sandstone, petrophysical properties
Abstract: In order to develop, maintain and deplete reservoirs economically around the globe, various measurements are needed with a high demand on natural core samples. The next stage in the life of every reservoir is a secondary or tertiary method to enhance productivity. However, to tailor the available methods and technologies to the reservoir, several screening processes, feasibility studies and pilot experiments are needed. As an aid to these, like a sensitivity analysis, continuous measurements are set up to study fluid flow, chemical reactions, additional recovery and much more, but for all of these, core samples are needed. The lack and high value of natural core samples yield that the demand cannot be satisfied from this source alone. The aim of the study was to create an artificially consolidated stone core sample, a model material, which can be suitable for being the subject of these experiments, with additional benefits in mass production and reservoir parameter-based quality control. In this article the authors wish to present partial results of a big study, this time with comparing the porosity, permeability, connate water and capillary pressure parameters of the core samples used with different after-cure techniques. The process of compaction was the same, but the overburden pressures and the effect of CO_2 rich curing were examined. For this, part of the samples was prone to high CO_2 environment for different timespans during the after treatment of the samples. The petrophysical parameters were then measured on all of the groups, including a control group and the CO_2 affected cores. The focus was on porosity, permeability, connate water saturation/wettability and capillary pressure measurements and the common features and differences in the yielded pore space's structure are summarized in this article.

1 Introduction

Natural rock core samples are pieces of rock mass taken from the reservoir in the wellbore with special core drilling devices. The cores are moved to the surface and the reason for sampling is to examine and identify the reservoir rock, its quality, and to try to get as much information as possible from the structure and characteristics of the porespace, along with the possibility of flow studies. These unique samples carry representative and useful information about the underlaying geological formations, thus their inspection is crucial. One part of the conducted measurements is aimed to define the petrophysical parameters of the reservoir. In order to establish these routine measurements, plugs are drilled from the whole cores, and to get these, the completeness of the whole core section is needed with unharmed surface and uncracked interior structure. The common problems arising are the lack of these whole core samples, the insufficient quality of those existing, or often the interval cored is not the representative section of the reservoir. The quantity of the core samples is also insufficient. In practice, the main cause of these problems, is cracked and incomplete whole core sections. As majority of the SCAL measurements are destroying the investigated samples during the measurement in terms of reproducibility, the number of possible conducted measurements is strictly finite. As the life of a reservoir proceeds, the use of secondary and tertiary depletion methods becomes inevitable. In order to tailor and screen these methods, and after selection, in order to monitor the effect of chemicals and materials used, a very high number of core samples would be needed, and their homogeneity is also a desired characteristic, increasing the overall demand much higher than the possible supply. As an answer to the challenges, the petroleum industry has developed and produced artificially consolidated core samples, thus there are multiple various methods to generate suitable cores.

Though having limited application, the generation of artificial core samples is cheaper and faster, and these cores often have even some benefits against natural core samples, in terms of uniform petrophysical parameters which can help easy monitoring of flooding chemicals. The way to the uniformity of the production is also a challenge and to achieve this the constant monitoring of the yielded

EFFECT OF CO2 REACH ENVIRONMENT ON THE PETROPHYSICAL PROPERTIES OF ARTIFICIALLY CONSOLIDATED CORE SAMPLES

Gyula Varga; Dániel Bánki; Tamás Fancsik

petrophysical parameters is needed throughout the development stage. As the sample size for RCAL and SCAL measurements is often given, that is another advantage in case of artificial consolidation that the size of the generated sample can be very easily controlled despite the fact that natural core samples are seldom complete, and often the addition of some space filling material is needed. Furthermore, the fact of artificial production opens a way to develop new measurement and control devices, because a much wider variety of sample sizes are now available. The petrophysical characteristics are now a function of a production process, being not prone to reservoir heterogeneity, but in order to achieve this, several test measurements needed to find out the correct generation process to the current demand. Evaluation of the routine core analysis results is a must and the only way to tailor the process well enough to be able to substitute the natural samples with artificial ones. As a step further, comparison also should be made between those too, and the artificial material should resemble the original one, thus if needed, the production method is altered in order to get the same petrophysical property ranges.

The aim of this study to introduce the basics of the production and to compare the effects on the same composition but different confining pressure and different after treatment methods of the artificial core samples. The two parameters were the pressure of compaction, and the treatment material, as some part of the cores were prone to vapour only and the others to CO_2 rich environment. The compared measurements are regarding porosity permeability, capillary pressure and relative permeability.

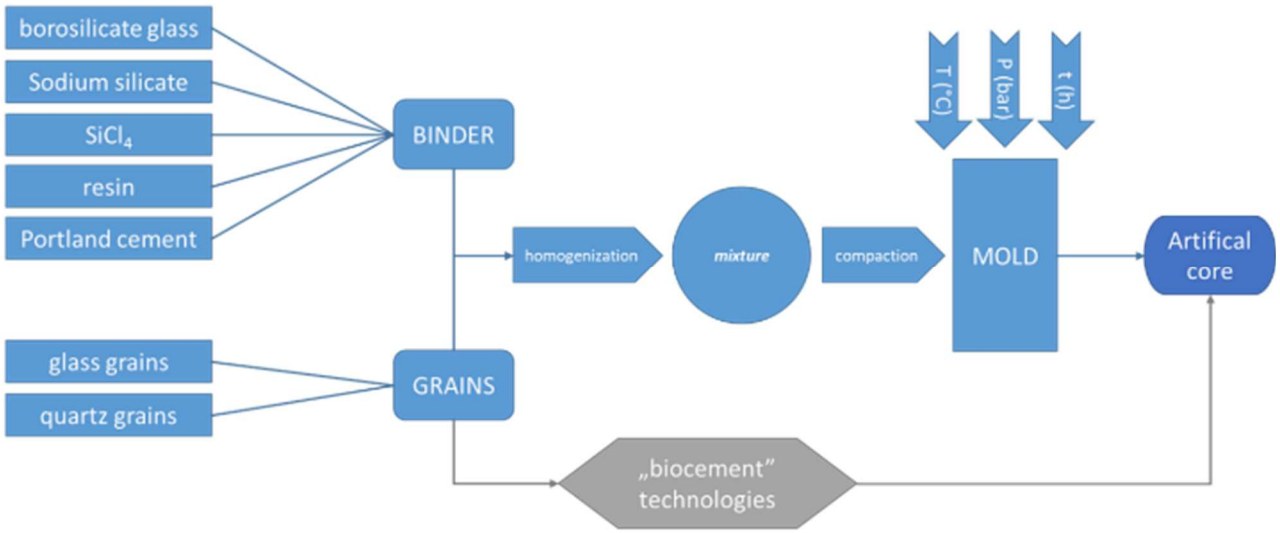

Figure 1 Possible methods for artificial samples

2 Main types of artificial core samples based on literature review

The history of the first attempts on creating artificially consolidated rock samples in order to substitute natural ones dates back for almost two decades [1]. As the manufacturing technology improved, new materials and methods were used on order to match the areas of interest. Based on technical literature, it is indeed possible, that using various methods (Figure 1), core samples can be generated, and these can be tuned to have similar petrophysical properties to hydrocarbon reservoirs, being suitable for conducting petroleum industry-based laboratory measurements.

To start the process the primary materials should be the same type and purpose as in the reservoir rocks. The main materials are a matrix and a bond forming material, a cement. To achieve a rock matrix, most of the methods use natural quartz particles [2-10], while some others use artificial glass beads [11], waste glass and mashed rock [12], or waste rock mud [13].

The secondary component is the cementing material, which connects the particles and solidifies the structure. These components can vary based on the different future application areas of the samples. With the application of sodium silicate or any alkaline silicate, the resulting cement material and sample is rigid, thus having quite low mechanical resistance [2,4,6,14,15]. Besides having its own advantages, one must conclude that these materials can easily devitrification [15] in water-based environments, thus rendering their application in permeability measurements insufficient. As an improvement, the aim was the strengthen the bonds by [16], who added kaolinite-based additives to the cementing material. As per rigidity, other materials can be used such as borosilicate glass [3,17] or the strongly toxic silica tetrachloride [18]. Following the same ideas, to strengthen bonds, Portland's cement or other industrial cements can be used as a bonding material, also resulting in a rigid but suitable pore structure [8,19,20-22]. The usage of cement has another advantage in petroleum engineering, which is that the resulting pore structure will be more of a water wet

system, thus mimicking the reservoir rock structure more efficiently. Still on the rigid side, heat treatment of clay van also yields porous artificial samples [23-25]. When applying epoxy resin as a bonding material in the samples [26-30], the resulting artificial core is more plastic, and mechanically resistant, but, on the other hand, all of these cores exhibit moderate or strongly oil wet behaviour, which renders them inapplicable in measurements, or serious correction is needed in the evaluation process [30]. Their plasticity alone is also a big difference compared to conventional reservoir rocks.

As a third, rather independent method, microbial carbonate emission can also be used to generate artificial porous material [31-33]. First the construction industry applications were studied [31-37], then it was adopted as a trial to generate petroleum industry core samples, too [9,10,38].

If the components are finalised, a recipe is created. Once that part is ready, the next step is some sort of consolidation, solidification etc. As a start a thorough homogenisation is done, and the resulting material is a rock pulp/mud/dollop, which is put into a sample holder. To achieve sufficient density and consistence, several different devices can be used, which are based on the vibration and compaction principles [2,6,12,13]. According to the different methodologies, then this mixture is often put under certain pressure and temperature conditions in order to finalise the bond, structure and any reaction present within the sample. Pressure itself is a good analogue to the generation of sedimentary reservoir rocks, thus is a very important parameter to set up correctly. When a natural core is taken from the wellbore, even the pressure release is the same type compared to the release of the samples from the machine [5].

3 Design process, experiment plan

Based on our recent studies, there is possibility to alter the porosity and permeability values of the samples [39] based on the methodology, across a quite wide range (from reservoir engineering point of view). Based on the origin of the matrix material, there are two main sources of artificial core samples. One source is regarded as natural, which is the crushed shells of real whole core remnants, or any residue but from the given reservoir rock. The mining and riverbank sand sources are regarded as non-natural, but yet these are the preferred ones, as the representative recipe can be much more easily generated, and there are numerous cheap sources, which are having the same parameters as the typical Hungarian sedimentary reservoirs. The particles creating the matrix were between 110-150 micrometres in size. As a bonding material, industrial cement based gluing material was used.

In the first part of the experimental study, the matrix-cement ratio and the composition were the same in all of the samples. The parameters varying were the added water (12,1-13,19 g) and the pressure used during the 24-hour compaction period. The curing was 14 days in both cases at 10 bars and 45 °C (113 °F).

The difference in the second set of experiments was the curing process (Table 1). In the technical literature there is precedent of using the artificial samples to study CO_2 injection EOR methods [40], but the effect of that CO_2 to the resulting pore structure and permeability lacks proper documentation, thus becoming the aim of these measurements. The main parameters of the samples can be found in Table 2. There were 4 groups, part of the groups was prone to CO_2 rich environment, whereas the other parts were prone only to water vapour rich environment.

Table 1 The curing and types of the groups within the samples

2 weeks of CO_2	Group 1	Sample 1-6
1-1 week CO_2 and vapour	Group 2	Sample 7-12
1-1 week vapour and CO_2	Group 3	Sample 13-18
2 weeks of vapour	Group 4	Sample 19-24

After the core samples were ready and stable, the next step was the design of the measurements of comparison. As for the natural core samples, the idea was to recreate a typical RCAL routine, starting with porosity and effective and absolute permeability measurements. To identify the wettability and to categorise the resemblance to natural core samples, connate water saturation, capillary pressure curve and relative permeability were also examined on the artificial samples. In order to physically fit into the CoreTest URC-628 rock centrifuge, these samples were intentionally made shorter than the normal plugs, thus already exhibiting on of the benefits of the process (that one can easily choose the output size and form).

Table 2 Composition characteristics of the artificial samples

Sand (g)	178,80
Cement (g)	30,00
Water (g)	12,10
Sand: (Cement + Water) ratio	4,25
Cement-Water ratio	2,48
Sand-Cement ratio	5,96
110 µm - 150 µm	100,0%
Applied pressure (bar)	400
Duration under pressure (hr)	24:00:00
Temperature (°C)	~23
Number of strikes (Marshall)	6x
Curing period (hr)	~336:00

In order to prevent anomalies caused by end effects and to be in accordance with normal lab routine, the other

groups size was set with removing material from the two ends of the samples. If the ends are not removed, based on previous experience, the structures can be deviant near the end zones, which are affecting the results of the flooding-based experiments.

4 Porosity and permeability measurements

The porosity values of the artificial core samples were measure with Helium porosimeter and are displayed on Figure 2. The permeability values vs. the porosity results are displayed on Figure 3. The results of the measurements are presented in Table 3 The application of different water quantities did not create any major change in permeability, but the trend is that less water during production yields higher permeability. This phenomenon is much stronger in the artificial core samples which were created under high pressure values of 300-400 bars. On the pore-perm plot the distinctiveness of the different pressures can be easily seen. In terms of the created porespace, more than 10 percent decrease can be yielded with increasing the confining pressure from 200 to 400 bars. In these scenarios, the permeability values can also be varied utilising different pressures.

In the described particle size, the minimum permeability values were around 170 mD, while the maximum values scaled at around 1412 mD. According to the porosity measurements the minimum was 20,02% at 400 bars of confining pressure and 32,82% at lower pressures. The previous values are for the water sensitivity analysis.

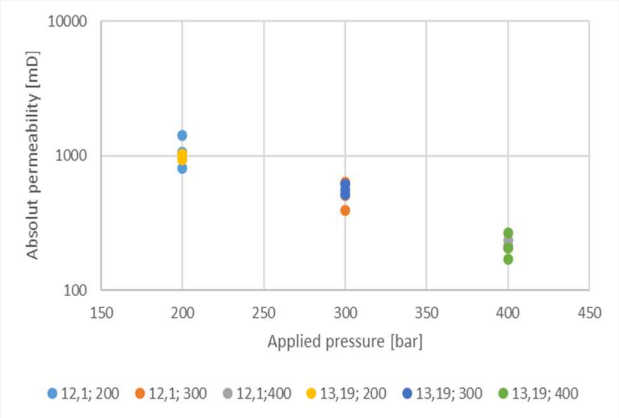

Figure 2 Absolute permeability values vs applied pressure of the 110-150 µm particle size artificial core samples

In the second part of the experiments, the difference was in the curing process. There were 4 groups as mentioned, one with 2 weeks in vapour only, one with 2 weeks of CO_2 only and two groups of 1 week in environment 1 and the other week of curing in environment 2, respectively, in accordance with Table 1. To clarify, within group 1 was the difference in added water only, as a sub-experiment. As the samples were created with a local developed method, the first part was also the determination of porosity. (All of the results are summarized in Table 3) The average porosity in the group which had 14 days of CO_2 exposure was 26,68% with the deviation of 1,73%. For the group which was cured with CO_2 for 7 days then with vapour for the second 7 days, the average porosity was 25,64% with a deviation of only 0,5%. In this group the reproductivity is the highest, from the 6 samples 3 exhibit differences in porosity only in the magnitude of 0,01-0,02%, and only one of the sets yielded a porosity above 26%. The third group (vapour curing for one week, then CO_2 curing for one week) three samples are the same type in terms of result such as in the previous group, overall porosity decreased a little bit to 25,99%, with the deviation of 1,47%. The last/control group (14 days of curing in vapour only) yielded a decrease in porosity, at an average of 24,44%. From the total of 24 samples, the 3 most dense are all in this group, porosity is below 24% for all of those ones.

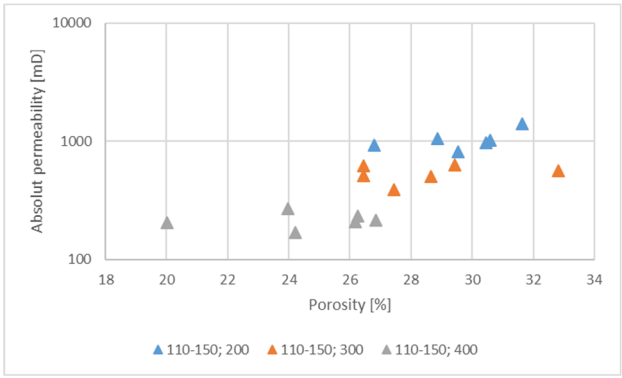

Figure 3 Porosity values vs absolute permeability values of the 110-150 µm particle size artificial core samples

The next parameter to measure and compare was absolute permeability, which was measured with Nitrogen gas. For the two weeks of CO_2 curing group, the values ranged between 15 and 89 mD. One sample is anomalous amongst these six, but the rest exhibit uniform behaviour. For the one-week CO_2 one week vapour curing group, the range of permeability is more or less the same, if trend needs to be stated, it is increasing in terms of permeability by a small amount. For group 3, treated with vapour first then CO_2, there is a significant increase in absolute permeability, with an average of 221 mD. For the two weeks of CO_2 only group this behaviour was the same, resulting in permeability values with the average of 205 mD.

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Table 3 Results of the porosity and permeability measurements in the groups of samples with different curing

		Number of sample	Porosity (%)	Absolut permeability (mD)	Effective permeability (mD)
Curing type	2 weeks CO_2	Sample 1	27,41	89	22
		Sample 2	28,36	35	21
		Sample 3	26,60	37	20
		Sample 4	26,44	18	12
		Sample 5	24,95	15	7
		Sample 6	26,30	17	9
	1 week CO_2 + 1 week water vapour	Sample 7	25,11	82	64
		Sample 8	26,14	36	28
		Sample 9	25,72	57	38
		Sample 10	25,71	38	32
		Sample 11	25,73	12	9
		Sample 12	25,42	13	10
	1 week water vapour +1 week CO_2	Sample 13	25,65	196	99
		Sample 14	26,67	258	148
		Sample 15	26,25	275	167
		Sample 16	24,52	89	70
		Sample 17	25,97	252	66
		Sample 18	26,86	257	226
	2 weeks water vap	Sample 19	26,47	231	98
		Sample 20	25,75	188	105
		Sample 21	22,73	162	77
		Sample 22	23,12	190	167
		Sample 23	23,73	217	88
		Sample 24	24,81	239	122

The third measurement in the study was the effective permeability measurement. using synthetical pore water, the composition of that is described in Table 4. The speed of the flood was 50ml/hour, and the key concept was to displace at least ten porespace equivalent water through each and every sample, and then take the average permeability of each measurement. For Group 1 the values are within a narrow range, with an average of 15 mD. For Group 2, despite having roughly 1 percent less porosity, this value was increased, with an average of 30 mD. For Group 3 there was a significant change in terms of an increase, the average effective permeability values were at around 129 mD. As per Group 4 the average was similar, being at around 110 mD, though the porosity values were the lowest in this group.

Table 4 Composition of the artificial pore water

Component	Quantity
	(g/l)
NaCl	0,5
$NaHCO_3$	2,6
CH3COONa	1,6
Total	4,7

As a secondary result of the experiments using flooding, it can be conducted that after further evaluation of the expelled fluids, there were no solid content or any residue washed out from the sample, thus rendering the artificial core samples stable enough for the previously stated expectations.

5 Capillary pressure and relative permeability measurements

In the last chapter of presenting the results, the authors wish to evaluate the results of the RCAL measurements regarding capillary pressure, relative permeability and connate water saturation. The measurements were conducted in every group of artificial cores with a CoreTest URC-628 rock centrifuge. After screening the characteristics for porosity and permeability, and having good results, the next step is to monitor the artificial cores as a hydrodynamic system, when wettability is present, and when two phases exist together, to find out its applicability in flooding experiments. On the other hand, if any difference is present compared to natural core samples, that still does not make any problem if a correlation is found and the values can be corrected.

During the RCAL measurements it was found that the cores are suitable for substitution, but the nature of the pore structures yielded a challenge to solve through the evaluation process. The problem was that the rock centrifuge gave reliable values on connate water saturation and capillary pressure, but the relative permeability curves were shifted to the right, to higher saturations. This can be caused by spontaneous imbibition and microfractures in the samples. The idea is that if microfractures are present, the water is expelled from the samples at much lower rotational speeds, thus much lower pressure, and the high-speed camera can detect the change, but arranges it to the wrong saturation, as the software thinks the samples are still almost fully saturated in the first stage of rotation. The mobile saturation range, however can be extracted from the capillary pressure curves, and using a normalisation, the relative permeability curves can be transformed to this range.

In terms of results, the 1 week one environment, 1-week other environment cores (Group 2,3) exhibited same behaviour, and the values scaled in between the 2 weeks of CO_2 and 2 weeks of pure vapour cured groups (Group 1-4). Thus, only the two “extremums” are shown in this article, groups 1 and 4, through one-one representative examples. In all of the groups, one common fact is, that all of the artificial cores generated exhibit water wet behaviour, which is desired, if the aim is to mimic cores from sandstone reservoirs. The magnitude is a little bit higher than in average reservoir conditions, but if this fact is known during the evaluation of the planned measurements using these samples, no problem is generated. One must state, that compared to epoxy resin artificial samples, these scenarios are much more

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Gyula Varga; Dániel Bánki; Tamás Fancsik

favourable, as correlation is easy, compared to the unreliability of the oil wet artificial cores.

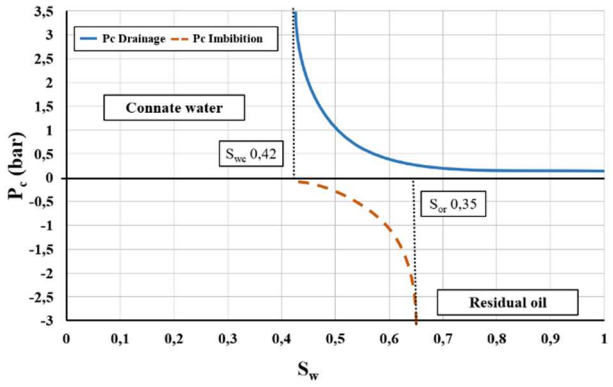

Figure 4 Capillary pressure curves of Sample 4 taken from the CO_2 cured group

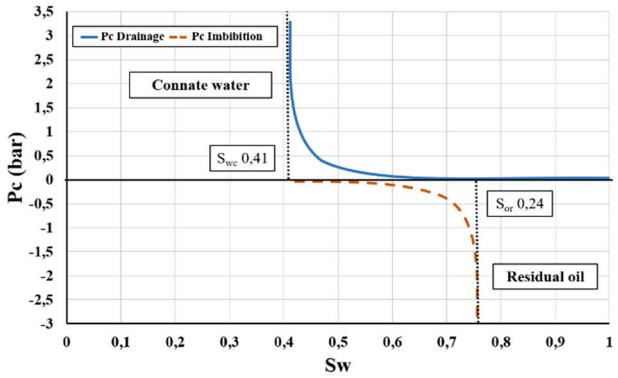

Figure 5 Capillary Pressure curves of Sample-20 taken from the vapour cured group

On Figures 4-5, the Capillary pressure curves are presented for Group 1 and 4. The connate water saturation of the samples ranged between 30-45%, being rational for sandstone rock samples, and being in the expected range, as even the bonding material type predicts water wet behaviour. The residual oil saturations ranged between 25-35%, being also in an expected and suitable range.

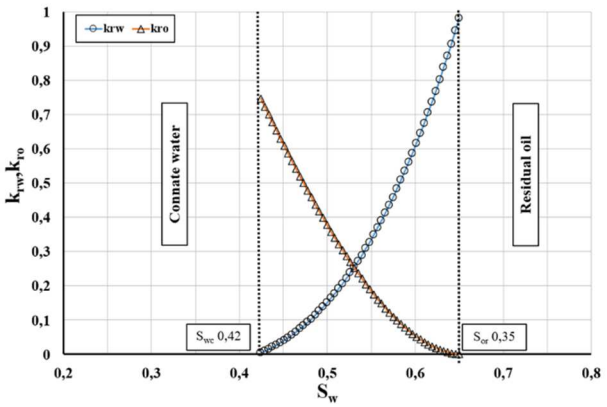

Figure 6 Relative permeability curves of Sample-4 taken from the CO_2 cured group

For the sample cured with CO_2 for two weeks, the mobile saturation range is between 42 and 65 percent. The pure vapour cured sample exhibit same behaviour setting the mobile saturation between 41 and 76 percent.

The relative permeability curves are also presented for Group 1 and 4. These were the curves which needed transformation based on the mobile saturation ranges shown by the capillary pressure curves. Figures 6-7 display the transformed relative permeability curves for the groups. The shape and form of the curves is realistic, having great resemblance to the natural sandstone core materials. Equilibrium saturation and endpoint saturation values are normal.

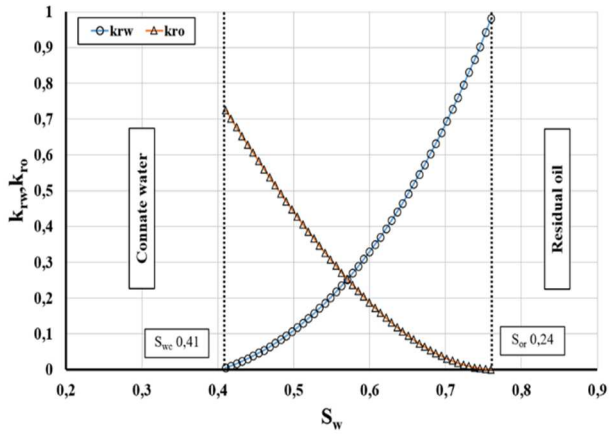

Figure 7 Relative permeability curves of Sample-20 taken from the vapour cured group

6 Conclusions

The aim of the study was to present a possible production method for artificially generated sandstone rock core samples, and to study the effects of different curing techniques applied to the yielded samples. Four groups were declared among the samples. Group 1 had curing in CO_2 rich environment only, for two weeks. Group 2 had one week in CO_2 and one week in water vapour. Group 3 had one week in water vapour and then one week in CO_2 rich environment. Group 4 had two weeks of pure water vapour curing, and in this group two types of samples were made, having difference in the added water to the cement material.

The differences in porosity and permeabilities were evaluated. According to added water, the smaller amount yielded higher permeability values. Based on curing, the vapour cured samples exhibited higher permeability, but relatively lower porosity values.

As for special core analysis, every group exhibited appropriate behaviour, in terms of connate wate saturation, capillary pressure and relative permeability, which means that these samples can be suitable for substituting real natural core samples in high sample demand monitoring type petroleum industry measurements.

Plans for the future include geomechanically measurements, and further experimentation on additives at

the bonding stage. The cores were stated to be suitable for substituting real cores in EOR measurements, and are now used in one such project, but this was not introduced in this article due to corporate secrecy. Another company is already having request for production of these types of cores to utilise them at their RCAL laboratory.

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DESIGNING VIRTUAL WORKPLACE USING UNITY 3D GAME ENGINE

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Abstract: Designing a workplace may be a challenging task. It is important to make sure that the new workplace will prevent unnecessary resource waste, but also create a safe working environment for employees. Therefore, creating a virtual copy of the workplace before its real-life implementation may help to eliminate design shortcomings. This article presents a methodology of creating a virtual workplace using a game engine – Unity 3D. The methodology describes basic principles and methods used for the creation of virtual workplace, from initial analysis to utilization. The user then can use a VR head-mounted device to see small details and possible shortcomings. Effectiveness of methodology was then evaluated by using it to visualize a bar-processing workplace.

1 Introduction

Nowadays, innovative solutions are rapidly proposed, and it is crucial to be able to implement these technologies most optimally [1]. Industry 4.0 influence creates an ideal environment for these implementations [2]. Virtual reality (VR) is slowly becoming a stable technology in many fields, such as aerospace, manufacturing, employee training, process simulation or manufacturing systems visualization [3,4]. Testing the proposed solution in a virtual world before its implementation can be crucial, especially with current trends focused on constant cost reduction [5]. Moreover, potential shortcomings and dangers can be captured in virtual simulations before a real-life implementation. Thanks to that, companies can focus on increasing the production speed and overall quality, while emphasizing the physical health of their employees [6]. Virtual reality can also become a new prime teaching method. With educational centres implementing this technology, VR can even become a new mass medium [7]. Virtual reality training programs for employees are also steadily rising in popularity.

However, to correctly integrate the technology into selected solutions, one needs to know the principles of creating VR capable environment. To ensure the sufficient immersion of VR user, it is important to create a virtual environment corresponding with its real-life counterpart, containing all its elements [8,9]. This is no easy task since correct replication of real environment requires simulation of its object, functions, and processes.

The presented methodology proposes a uniform method of creating a virtual workplace using a game engine Unity 3D. The methodology contains methods and principles to ensure the smooth workflow and minimalization of errors while focusing on creating an immersive virtual reality experience. The goal of the article is to enhance the current approach of virtual workplace design by unifying currently used methods into single methodology expanded with new principles to reduce total time and resources cost.

2 Methodology

The main purpose of the methodology is turning a designed workplace (2D layout) into virtual reality compatible form. It is a relatively complex process consisting of several tasks that need to be done. After completion of every necessary step, the user can walk through the created virtual workplace using a VR headset and additional accessories. such as controller (joystick). However, before the creation of a virtual workplace, some preparations are required. User must collect all necessary materials and references, such as layout, 3D models or

dimensions. After that, the process of building the virtual workplace using Unity 3D can begin.

A flowchart is presented in Figure 1. to ensure that methodology is straightforward and easy to understand. This flowchart shows all the necessary task and requirements for the project's completion step by step. The blue colour represents the preparation phase, where the user gathers and analyse all necessary data. These will serve as a foundation for the next stage to ensure accurate workplace design and visualization. The yellow colour represents the task done in the game engine Unity 3D. That includes 3D modelling of assets (with use of gathered references), virtual workplace creation and interaction programming (player movement). Finally, the design must be tested and found shortcomings corrected (green colour).

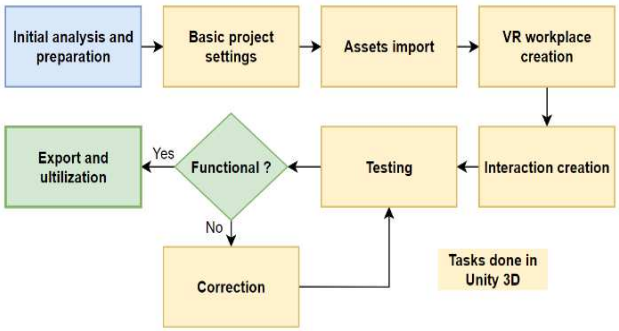

Figure 1 Virtual workplace creation methodology

2.1 Initial Analysis and Preparation

Initial analysis and preparation take place before the building of the virtual scene in Unity 3D. This stage includes every preparation task required for the successful completion of virtual workplace. When creating a virtual workplace, one of the most crucial requirements will often be its similarity with the real workplace. Therefore, the user must analyse every detail of the workplace, such as used machine tools, dimensions, or workplace layout. The best practice is to collect as many references as possible. This includes photos and video of the workplace, object dimensions and 2D layout. Appropriate references will make the creation of 3D assets and the virtual workplace itself much easier.

Another important part of the preparation phase is object identification. The real workplace consists of many objects, however, not every object needs to be modelled for satisfactory workplace visualization. Therefore, the user must identify crucial objects that need to be recreated in 3D. This includes every part of the workplace, that is necessary for its correct functioning, such as machine tools, storage units, manipulation units or transport vehicles. On top of that, objects should not be as detailed as in real life. A number of details significantly increases performance requirements [10]. For most objects, it is enough that they are recognizable on sight. Only objects that can be more detailed are the main entities of the workplace, such as machine tools.

If the user has access to all models beforehand, it is good practice to check all of them before using them. Some of them may have to be simplified to reduce their performance impact. Simplification process can be done in 3D modelling software. The complexity of an object is determined by the number of vertices (number of points), which represents the total quantity of vertices used to build a 3D model. Vertices are basic elements of a 3D model. With an increasing number of vertices increases the complexity of its geometry, therefore the performance requirements.

Available computing power is limited and so should be limited the number of vertices of the entire virtual workplace. A number of vertices in one 3D model determines the impact on the performance of virtual workplace application. If the said object is used multiple times, the impact is multiplied. Many vertices will allow an object to look very detailed, but slower computers may have trouble to handle a lot of detailed objects. Therefore, if objects do not belong in the category of the most important workplace objects, they should be simplified as much as possible.

2.2 Basic Project Settings

With the competition of all necessary analysis and preparation, the user has all necessary information to proceed. The following task will be completed using the game engine Unity 3D. Unity 3D is a game engine used for the creation of various games and application. For this project, the user will not use any complex Unity 3D function, so even a complete beginner can learn basics quickly, and then proceed to follow the methodology itself.

Firstly, the user needs to decide on a platform that scene will be built on. The two most valid options are PC (Windows) or a smartphone (Android, iOS). However, these two variants offer a different experience. Smartphone VR headset offers a cheap, but mobile VR experience, in exchange for low immersion and interaction options. On the other hand, desktop VR headset offers much vivid experience with a rich spectrum of interaction, complemented by a much higher price. Depending on the chosen platform, the user then may download a software development kit (SDK) that contains a lot of useful tools. SDKs such as GoogleVR or SteamVR can be downloaded from the internet for free. Subsequently, it is time to create a new project in Unity 3D and set basic parameters depending on preferred options. User must select platform he/she decided on, import SDK, if necessary, and finally, fill in basic project settings (such as name or concrete VR hardware) Figure 2 shows the process of platform and project setup.

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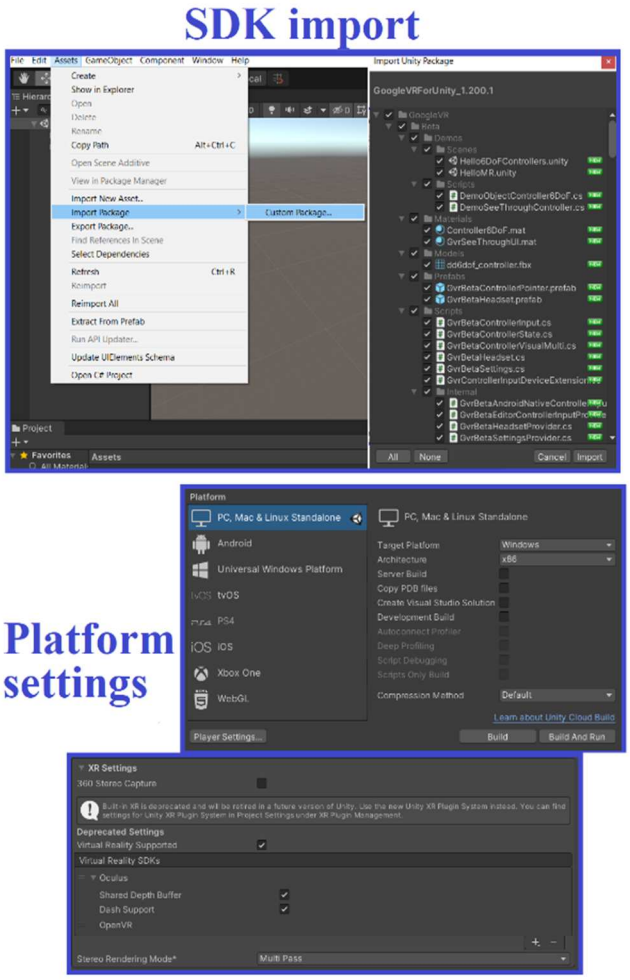

Figure 2 Basic project settings

2.3 Assets Import

Initial preparation should provide the user with all necessary 3D models needed for virtual workplace creation. Before building a virtual workplace itself, all these models (assets) need to be imported into Unity 3D (Figure 3). User needs to make sure that models are in a format supported by this game engine.

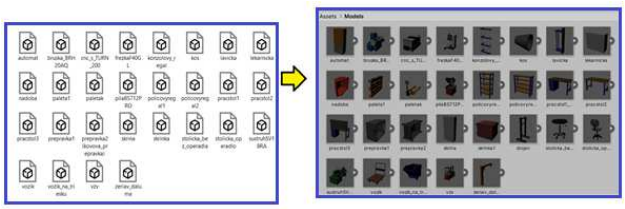

Figure 3 Assets import

2.4 VR Workplace Creation

With the library of 3D models imported into the game engine, the user can proceed to build a virtual workplace. Virtual workplace creation is a relatively simple process. The main goal is to place each object according to its position in a real workplace. Depending on the virtual workplace purpose, distances between may be required to be identical as in the real workplace design. Therefore, built-in tools, such as a coordinate system may help to achieve this requirement. While building the virtual workplace, the user simply chooses the 3D model from the library and place it in the correct position. An example of Unity 3D workflow is shown in Figure 4.

It is a great practice to establish a uniform method of virtual workplace creation to avoid mistakes. Placing objects in an orderly fashion will make the process faster and more straightforward [10]. Objects can be divided into groups depending on:

- Type of the object.
- Purpose of the object in the workplace.
- Position of the objects in the layout.
- Importance of the object for the workplace processes.

After creating a group of particular types, objects can be divided into them according to set parameters. These groups organized into a specific order. The user will then follow this order to place the group into the scene.

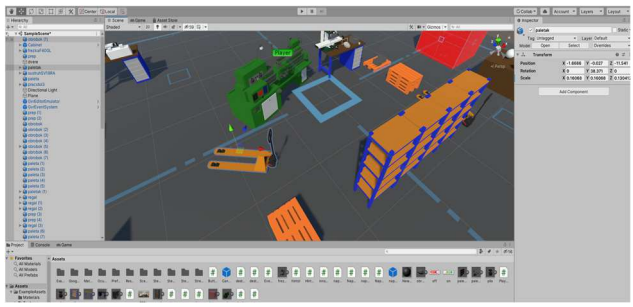

Figure 4 Virtual workplace creation

2.5 Interactions Creation

After completing the previous step, the virtual workplace is built. However, the application still lacks the means of movement for the user. This can be achieved by creating a script. Scripts are programs created with programming language supported by selected software. This methodology uses the game engine Unity 3D, therefore scripts were created using C#, which is a programming language supported by Unity 3D. However, depending on software selection, many other programming languages can be used, such as C++ or JavaScript. They allow the user to create various scenarios to make a scene interactable and more vivid. The most basic script for the virtual workplace is the addition of horizontal movement for a player. This may be enough if the goal of the scene is to showcase the created workplace that represents a real or designed space. User needs to know the purpose of the VR scene he/she is creating and write required scripts accordingly. However, it is possible to find various scripts online, so even user with little programming experience can use and combine those, to achieve the state he/she needs.

2.6 Testing

Before exporting the application, it is important to check if everything is working correctly. Player movement may have some flaws or virtual workplace does not precisely copy initial workplace design. Testing can take place in Unity 3D, the application does not have to be exported. After plugging in the VR hardware, the application can be built and launched directly in Unity 3D. Fixing every occurred problem is necessary for the smooth functioning of the application. Any inaccuracies can hinder the usability of the application, or even make it obsolete.

3 Practical use

For presented methodology utilization, it is crucial to evaluate the potential and effectiveness of the methodology. The methodology provides needs to provide all necessary information, while remaining concise and easy to use. To demonstrate the capability of the presented methodology, it was tested in practical use. Concrete VR ready virtual workplace was created using its principles. Firstly, a 2D layout of a bar material processing workplace was designed. The objective was to transform the assigned 2D layout into VR ready virtual workplace as a form of project visualization. This VR workplace was then used for the presentation of the proposed workplace. Presentation participants could use the VR headset and controller to walk through the virtual 3D representation of the designed 2D layout. A simple mobile VR headset was used, but for the presentation purpose, which minimize the user interaction options, it is a viable and significantly cheaper method. Thanks to that, participants had an opportunity to get a much closer look at every detail of the proposed project. Written scripts and VR hardware allowed them to explore every part of the virtual workplace. Figure 5 shows the process of creating a virtual workplace from the assigned 2D layout. Figure. 6 shows the VR application itself.

The process of workplace visualisation using virtual reality was executed using the proposed methodology. After analysing provided data and collecting necessary references, every missing 3D asset was created. Created assets and references were then used to create a virtual copy of a workplace using the Unity 3D game engine. To ensure the means of movement for the virtual workplace, a C# was created and integrated into the application. Finally, the virtual workplace was tested to fix any problems. After that, the application was ready for its utilization.

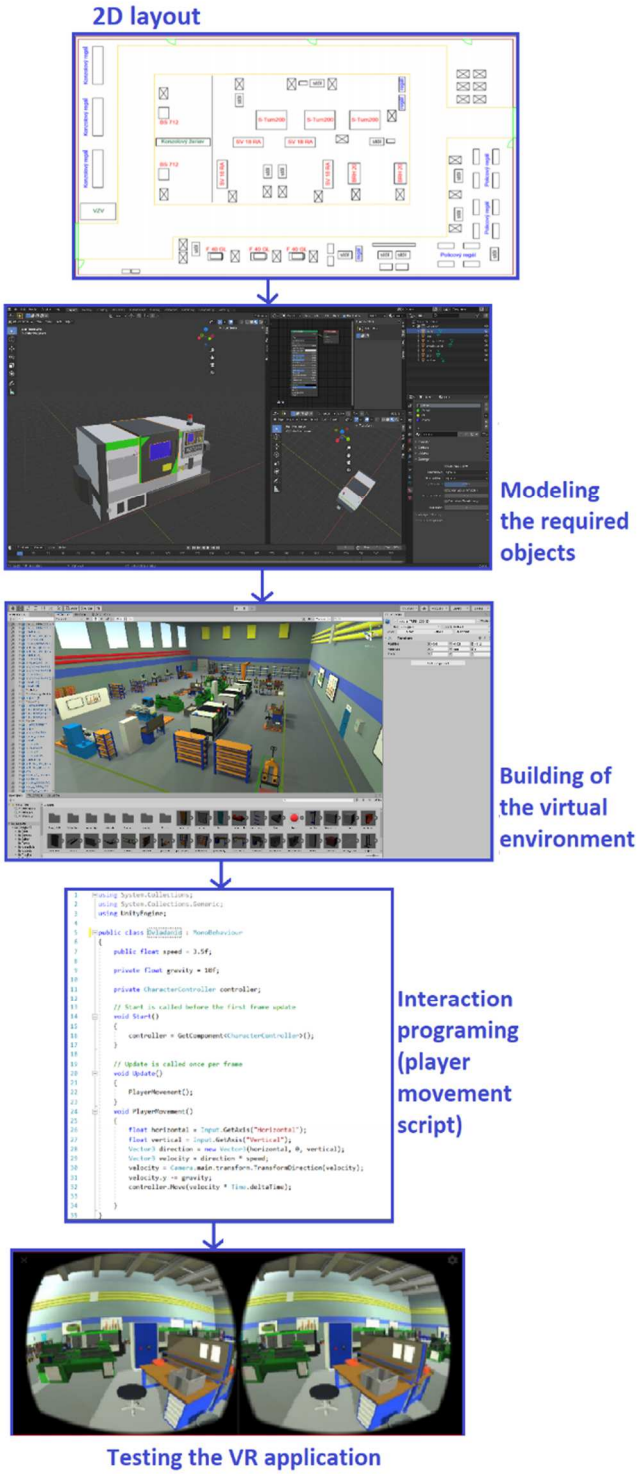

Figure 5 Creating a virtual workplace using Unity 3D

Figure 6 VR application

4 Conclusion

The presented article proposes the methodology for the design and visualization of the virtual workplace. The methodology presents and straightforward way of virtual workplace creation, covering every necessary stage and its methods and principles. The methodology attempts to streamline the process of virtual workplace creation, unifying known methods and enhancing them ensuring smooth workflow and more effective use of time and resources.

The effectiveness of the methodology was evaluated in practical use. A concrete VR ready scene was created. The main goal was to turn an assigned 2D layout of a bar-processing manufacturing system into VR capable 3D environment. The user used the presented methodology for every necessary step. As the result, the user-created a virtual environment capable of VR immersion suitable for its goal, which was the presentation of the proposed workplace.

The practical test shows that the methodology is suitable for the process of virtual workplace creation. In the near future, additional tests will be held to improve the workflow to make it an even more powerful tool in the field of virtual reality.

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