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A novel DEA model for hospital performance evaluation based on the measurement of efficiency, effectiveness, and productivity

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ABSTRACT

Hospitals are the most important and costly component of the healthcare system. Therefore, hospital performance evaluation (HPE) is an important issue for the managers of these centres. This paper presents a new approach for HPE that can be used to calculate the efficiency, effectiveness, and productivity of hospitals simultaneously. Efficiency refers to the ratio of inputs and outputs, effectiveness refers to the extent to which outputs align with predetermined goals, and productivity refers to the sum of both efficiency and effectiveness. To this end, a Data Envelopment Analysis (DEA) model is developed to simultaneously measure the efficiency, effectiveness, and productivity (DEA-EEP) of hospitals. DEA is a linear programming technique that in its traditional form, calculates the performance of similar decision-making units (DMUs) that have both inputs and outputs. In this study, the inputs are the number of health workers, the number of other staff, and the number of patient beds; while the outputs are the bed occupancy rate and the bed turnover rate. A target value is set for each output to measure the effectiveness of hospitals. The advantage of the developed model is the ability to provide a solution for non-productive units so that they can improve their performance by changing their inputs and outputs. In the case study, data of 11 hospitals in Tehran were evaluated for a 3-year period. Based on the results, some hospitals experienced an upward trend in the period, but the efficiency, effectiveness, and productivity scores of most hospitals fluctuated and did not have a growing trend. This indicates that although most hospitals sought to improve the quality of their services, they needed to take more serious steps.

KEY WORDS

hospital performance evaluation (HPE), Data Envelopment Analysis (DEA), efficiency, effectiveness, productivity

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Introduction

Healthcare centres are concerned with the lives of people in the community, and since community health is vital, improving various aspects of the performance of these centres has always been a concern in developing countries (Lupo, 2013). Like all other organisations active in the healthcare sector, hospitals are complex social systems (Buchelt et al., 2017). Hospitals are the most important and costly part of the healthcare system; the key role of hospitals in providing health care

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services has shown their profound impact on the proper functioning of the healthcare system. This has forced hospitals to improve their performance (Kohl et al., 2018). Patients regularly experience failed attempts to effectively meet their needs for medical services (Twardowska & Jewczak, 2017). Improved performance requires proper resource allocation, which in turn requires HPE (Yang, 2017). The use of the DEA technique for HPE has attracted researcher attention. Existence of numerous applied studies on the use of DEA for hospital evaluation demonstrates the importance of using this technique (O'Neill et al., 2008). DEA is based on mathematical programming and has been widely used to evaluate the relative performance of similar DMUs. In addition, the capability of analysing the DEA results has consistently increased the applicability of the method in various contexts (Nassiri & Singh, 2009).

There are numerous studies of DEA application in evaluating effectiveness, such as industry (Docekalova & Bockova, 2013; Nazarko & Chodakowska, 2015) companies (Sajnóg, 2015; Grmanová & Pukala, 2018), countries (Chodakowska & Nazarko, 2017a), railway industry (Lan & Lin, 2003; Yu & Lin, 2008), urban transit systems (Karlaftis, 2004), hotel-chain services (Keh et al., 2005), healthcare work (Stefko et al., 2016), Spanish football teams (García-Sánchez, 2007), public higher education institutions (Nazarko & Šaparauskas, 2014), public sector banks (Kumar & Gulati, 2010), couriers and messengers (Chodakowska & Nazarko, 2017b), airlines (Tavassoli et al., 2014), and supply chains (Azadi et al., 2015).

Numerous studies have been conducted on HPE, but almost none of them have simultaneously measured hospital efficiency, effectiveness, and productivity. Traditional DEA models measure the efficiency of DMUs but the DEA-EEP model presented in this study, simultaneously measures the efficiency, effectiveness, and productivity of DMUs. In the related literature, efficiency refers to the inputs-outputs ratio, effectiveness refers to the extent to which outputs align with predetermined goals, and productivity refers to the sum of both efficiency and effectiveness. In addition to simultaneously measuring the efficiency, effectiveness, and productivity, the DEA-EEP model also provides a capability for non-productive units so that they can improve their productivity. The DEA-EEP model provides a new framework for HPE. Efficiency alone cannot reflect the performance of a hospital because the DEA model shows performance compared to similar units. In that way, at least one of DMUs (the best one) will assumedly work perfectly even though its performance is very low; but the proposed approach can create a comprehensive framework for evaluating hospitals by simultaneously measuring the efficiency, effectiveness, and productivity.

In the case study, 11 hospitals in Tehran were evaluated for the period 2016–2018. Once inputs and outputs are identified, experts set goals for the outputs to measure the effectiveness of hospitals in achieving their goals using the DEA-EEP model.

The rest of the article is organised as follows. Section 1 reviews research literature that focuses on the use of DEA in the evaluation of hospitals and treatment centres. Section 2 describes the DEA-EEP model for HPE. Application of the proposed method in evaluating the actual cases of hospitals in Iran is described in Section 3. Section 4 includes a discussion of the evaluation results. The conclusion and directions for future research are presented in the final section.

1. Literature review

This section reviews the related studies and evaluation methods of healthcare centres. Table 1 shows methods and their applications in the related studies. Table 2 shows the inputs and outputs of the DEA-EEP model, which are selected based on the literature review and expert opinions.

Bannick and Ozcan (1995) used the DEA model to compare the performance of hospitals of the US Department of Health and the Department of Defence; the results of their study showed that the efficiency of the Department of Defence hospitals was significantly higher than that of the Department of Health hospitals.

Ersoy et al. (1997) evaluated the technical efficiencies of Turkish hospitals using DEA. The results of their study showed that less than 10 percent of these hospitals were efficient compared to other hospitals.

In another study, the effect of semi-constant inputs on the efficiency of the emergency department of a hospital in Montreal was investigated; they proposed modified DEA with semi-constant inputs (Ouellette & Vierstraete, 2004).

A DEA-based performance evaluation model was presented by O'Neill et al. (2008), who classified inputs and outputs in more detail and selected them with regard to the local environment. The authors used window analysis. Their method made it possible to perform HPE over multiple periods.

Yawe (2010) used the Super-Efficiency approach in DEA to analyse and rank the hospital performance and the BSC method criteria in the model to perform HPE.

Chuang et al. (2011) used a combination of DEA-artificial neural network and DEA-assurance region model to analyse hospital data and evaluate hospital performance. Then, they discussed the efficiency and inefficiency of hospitals using the regression.

Mitropoulos et al. (2015) used a combination of stochastic DEA and Bayesian analysis to calculate hospital efficiency scores in Greece. Bayesian analysis was used to generate a statistical model and create a simulation platform to analyse data of alternatives, and then calculated the efficiency scores of hospitals using the DEA model.

Rezaee and Karimdadi (2015) examined the effect of geographical location on the hospital performance. They categorised hospitals into different groups by province. Hospitals of each group were evaluated in a similar geographical environment. Then, they evaluated the performance of hospitals in different geographical locations using the multi-group DEA model.

Prakash and Annapoorni (2015) used the DEA method to calculate the technical efficiency (TE) of hospitals in the state of Tamil Nadu in India. The results of their study showed that only 29% of hospitals were efficient.

Gholami et al. (2015) used the two-stage Bootstrap DEA and two-year information of 187 hospitals in the United States to demonstrate the impact of IT investment on quality and the impact of quality on the operational efficiency of the hospitals.

Rouyendegh et al. (2016) proposed a hybrid HPE approach based on DEA and FAHP. The method combined the advantages of both DEA and FAHP methods to obtain optimal weights.

Chowdhury and Zelenyuk (2016) evaluated the performance of hospital services in Ontario, Canada, using DEA with Bootstrap and regression. They estimated the efficiency through the DEA, and then calculated the distribution of efficiency across different geographic locations, educational settings, and sizes using the two-stage Bootstrap method.

Lobo et al. (2016) used the Dynamic Data Envelopment Analysis (DDEA) method to evaluate university hospital performance in different years. Determining the efficiency scores for the annual performance of hospitals and monitoring the variation of these scores were among the benefits of their method.

Khushalani and Ozcan (2017) used the Dynamic Network DEA to evaluate the performance of hospital

Tab. 1. Summary of the techniques in HPE

Author(s)	Technique(s) used	Application
Bannick and Ozcan (1995)	DEA	Hospitals of the US Department of Defence
Ersoy et al. (1997)	DEA	Turkish acute general hospitals
Ouellette and Vierstraete (2004)	DEA	Hospital emergency services in Montreal
O'Neill et al. (2008)	DEA	Systematic review of previous studies
Weng et al. (2009)	DEA	Iowa Hospital Association (IHA)
(Yawe, 2010)	DEA	Hospital Performance Evaluation in Uganda
Chuang et al. (2011)	DEA and regression tree	Taiwan's hospital
Mitropoulos et al. (2015)	Stochastic DEA and Bayesian analysis	Greek public hospitals
Rezaee and Karimdadi (2015)	Multi-group DEA	Iranian hospitals
Prakash and Annapoorni (2015)	DEA	Hospitals of Tamil Nadu State in India
Gholami et al. (2015)	DEA	US hospitals
Rouyendegh et al. (2016)	DEA-FAHP	Hospitals in Turkey
Chowdhury and Zelenyuk (2016)	DEA with truncated regression	Hospital services in Ontario
Lobo et al. (2016)	DEA	Brazilian hospitals
Khushalani and Ozcan (2017)	Dynamic Network DEA	USA Hospital
Kang et al. (2017)	DEA	USA Hospital
Johannessen et al. (2017)	DEA and panel analysis	Norwegian hospitals
Chen et al. (2017)	DEA	Pennsylvania hospitals
Haghighi and Torabi (2018)	BWM and DEA	A real general hospital
Zare et al. (2018)	DEA-Game theory	Iran hospitals
Omrani et al. (2018)	Fuzzy Clustering DEA-Game theory	Iran hospitals
This Study	**New DEA Model**	**Hospitals of Tehran**

subunits, including surgical care, medical care and quality. The results of their study showed that the efficiency of hospitals increased during the studied period.

Kang et al. (2017) used DEA to evaluate the performance of the hospital emergency department. They concluded that many emergency departments needed to re-engineer their processes to improve their performance.

Johannessen et al. (2017) used DEA to evaluate the performance of physicians at a hospital in Norway. Their study showed that more attention should be paid to employees with multiple skills.

Chen et al. (2017) examined the impact of a recession on hospital performance; they concluded that hospital performance declined after the recession.

Haghighi and Torabi (2018) evaluated a hospital information system as one of the most important factors affecting patient satisfaction and health. They used BWM to calculate the weights of the evaluation indicators and then evaluated the performance of each unit using DEA.

Zare et al. (2018) used a combination of DEA and Game theory to measure the performance of health centres in Iran.

Omrani et al. (2018) used DEA based on clustering for DMUs under uncertain condition; they expanded the method to measure the performance of hospitals in different provinces.

In the research literature, different DEA models have been proposed for HPE, but most of these models only seek to measure hospital efficiency. Whether or not predetermined goals of hospitals have been met can be determined by measuring hospitals effectiveness. The DEA-EEP model can measure efficacy and effectiveness simultaneously and provide a more comprehensive assessment of hospitals.

In the evaluation of healthcare centres, selecting efficient inputs and outputs is crucial. In this study, inputs and outputs are selected according to the expert opinions and the review of existing literature. In the case study, which included Iranian hospitals, the authors of the article attempted to select indicators that correctly measured the hospital performance.

2. Proposed Method

This section presents an integrated DEA approach, in which the performance of hospitals in achieving their goals is addressed in addition to the efficiency of hospitals. The framework of the proposed method is shown in Fig. 1. In the first step, the authors of the article use DEA to measure efficiency. The second step shows how DEA can be used to measure the effectiveness of DMUs. Then, the DEA-EEP model is described, which can measure efficiency, effectiveness, and productivity simultaneously. Also, the proposed DEA-EEP model can offer suggestions for improving the inefficient and ineffective units. This model seeks to improve the ability to evaluate performance by using the dual

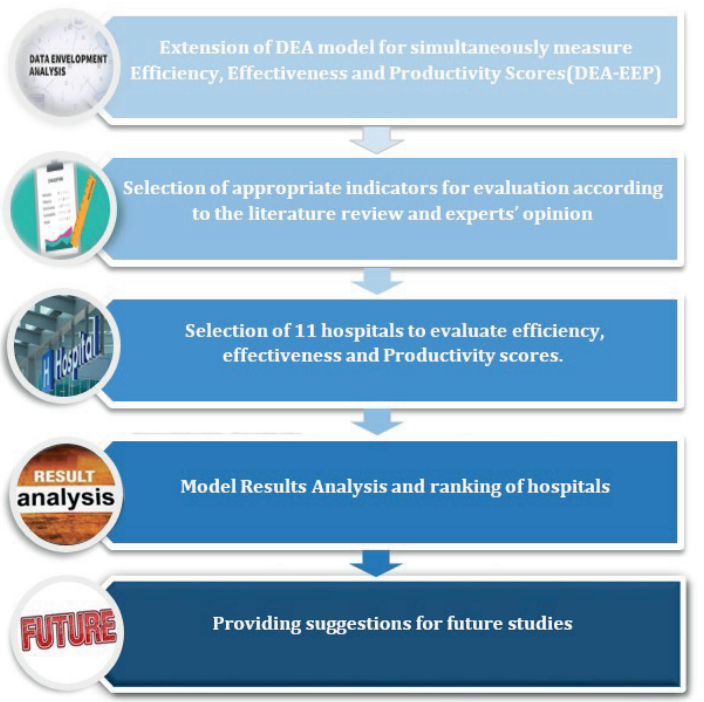

Fig. 1. Proposed method framework

problem and adding auxiliary variables. It also shows the numbers of input losses and output deficiencies. The inputs losses can be calculated by adding an auxiliary variable; if the value of this variable approaches zero, the inefficient unit becomes efficient. Deficiency of each output can also be calculated with regard to various inputs. Also, the DEA-EEP model has an auxiliary variable that represents the deficiency in the outputs relative to the predetermined target values. In this model, because it is assumed that the target value is fixed and optimally selected, the value of the target deficiency auxiliary variable is always zero. As there is no need to improve the target value and it is used only to evaluate the effectiveness of the DMUs, the proposed method uses the principle of "constant returns to scale" to derive relationships for measuring the effectiveness. The DEA-EEP model demonstrates efficient, effective and reference units for inefficient and ineffective units so that they can increase their efficiency and effectiveness. For example, if a DMU is fully efficient and is designated by the model as a reference unit for an inefficient unit, that inefficient unit should consider this reference unit as a model for achieving efficiency.

Russell's model based on auxiliary variables was used to calculate the efficiencies of the units (Pastor et al., 1999). The linear form of this model is shown as Model (1). Table 2 shows the sets, parameters, and variables used in this study.

The DEA model in the input-oriented mode and with constant returns to scale was described in the study by Charnes et al., 1978. In this study, the dual problem was used to calculate the effectiveness, except that the problem was target-oriented rather than input-oriented. Effectiveness shows how a company can meet the set targets (Tavassoli et al., 2014). In this study, effectiveness is defined as the output-to-target ratio. In the DEA-EEP model, it is assumed that the target is always ideal and unchangeable. For measuring the effectiveness, the problem is considered in a target-oriented mode, and the values of auxiliary variables for the targets are always zero. This means that there is no deficiency in any target. The effectiveness is measured using Model (2).

$$\begin{aligned}
&\text{Min } \beta - \frac{1}{m}\sum_{i=1}^{m}\frac{t_i^-}{x_{io}} \\
&st. \\
&\beta + \frac{1}{s}\sum_{r=1}^{s}\frac{t_r^+}{y_{ro}} = 1 \\
&\sum_{j=1}^{n}\mu_j x_{ij} = \beta x_{io} - t_i^- \,, i \in \mathbb{N}_m \\
&\sum_{j=1}^{n}\mu_j y_{rj} = \beta y_{ro} + t_r^+ \,, r \in \mathbb{N}_s \\
&\beta, \mu_j, t_i^-, t_r^+ \geq 0
\end{aligned} \tag{1}$$

$$\begin{aligned}
&\text{Min } \theta \\
&st. \\
&\sum_{j=1}^{n}\lambda_j g_{tj} + s_t^- = \theta g_{to} \,, t \in \mathbb{N}_T \\
&\sum_{j=1}^{n}\lambda_j y_{rj} - s_r^+ = y_{ro} \,, r \in \mathbb{N}_s \\
&\lambda_j, s_t^-, s_r^+ \geq 0
\end{aligned} \tag{2}$$

Tab. 2. Definition of sets, parameters, and variables

		Description
Sets	$i \in I = \{1,2,\dots,m\}$	Inputs
	$r \in R = \{1,2,\dots,s\}$	Outputs
	$t \in G = \{1,2,\dots,t\}$	Goals
	$j \in D = \{1,2,\dots,n\}$	DMU_s
Parameters	x_{ij}	i-th input of j-th DMU
	y_{rj}	r-th output of j-th DMU
	g_{tj}	t-th target of j-th DMU
	x_{io}	i-th input of DMU_o
	y_{ro}	r-th output of DMU_o
	g_{to}	t-th target of DMU_o
Variables	μ_j, λ_j	Dual variables of the problem
	β	The variable added for linearization
	t_i^-	Total maximum of input losses
	t_r^+	Total maximum of outputs that should have been produced with regard to the inputs, but they are not actually produced
	s_t^-	Total maximum of target deficiencies
	s_r^+	Total maximum of outputs that should have been produced with regard to the target values, but they are not actually produced
	ϕ	Efficiency of DMU_o
	θ	Effectiveness of DMU_o

By combining Models (1) and (2), the DEA-EEP model is obtained that can simultaneously measure the efficiency, effectiveness, and productivity of hospital units. The DMUo is the unit that its efficiency and effectiveness are calculated relative to other units at each run of the model. The DEA-EEP model is written as Model (3).

$$
\begin{aligned}
&\text{Min } \phi + \theta \\
&st. \\
&\beta - \frac{1}{m}\sum_{i=1}^{m}\frac{t_i^-}{x_{io}} - \phi \le 0 \\
&\beta + \frac{1}{s}\sum_{r=1}^{s}\frac{t_r^+}{y_{ro}} = 1 \\
&\sum_{j=1}^{n}\mu_j x_{ij} = \beta x_{io} - t_i^- \,, i \in \mathbb{N}_m \\
&\sum_{j=1}^{n}\mu_j y_{rj} = \beta y_{ro} + t_r^+ \,, r \in \mathbb{N}_s \\
&\sum_{j=1}^{n}\lambda_j g_{tj} + s_t^- = \theta g_{to} \,, t \in \mathbb{N}_T \\
&\sum_{j=1}^{n}\lambda_j y_{rj} - s_r^+ = y_{ro} \,, r \in \mathbb{N}_s \\
&\beta, \mu_j, t_i^-, t_r^+, \lambda_j, s_t^-, s_r^+ \ge 0
\end{aligned}
\tag{3}
$$

The DEA-EEP model is solved once for each hospital per each year. The value of productivity for each hospital unit is in the range of 0 to 2.

Suppose that $(\phi^*, \theta^*, t_i^{-^*}, t_r^{+^*}, s_t^{-^*}, s_r^{+^*}, \mu_j^*, \lambda_j^*)$ is the optimal solution of model (3) for DMUo, then the following situations can exist:

- If $\phi^* = 1$ and we have $t_i^{-^*} = 0$ and $t_r^{+^*} = 0$ in the optimal solution, then the DMU_o is "strongly efficient".
- If $\phi^* = 1$ and we have $t_i^{-^*} \neq 0$ and $t_r^{+^*} \neq 0$ in the optimal solution, then the DMU_o is "weakly efficient".
- If $\phi^* < 1$, then the DMU_o is inefficient.
- If $\theta^* = 1$ and we have $s_t^{-^*} = 0$ and $s_r^{+^*} = 0$ in the optimal solution, then the DMU_o is "strongly effective".
- If $\theta^* = 1$ and we have $s_t^{-^*} \neq 0$and $s_r^{+^*} \neq 0$ in the optimal solution, then the DMU_o is "weakly effective".
- If $\theta^* < 1$ then the DMU_o is "ineffective".

If $\phi^* = 1$ and we have $t_i^{-^*} = 0$ and $t_r^{+^*} = 0$ in the optimal solution, and If $\theta^* = 1$ and we have $s_t^{-^*} = 0$ and $s_r^{+^*} = 0$ in the optimal solution, then the DMUo is "strongly productive"; otherwise the DMUo is "weakly productive" or it "unproductive".

3. Research results

In this Section, several Iranian hospitals are evaluated in a real case study using the DEA-EEP model. To make DMUS more homogeneous, 11 hospitals were selected from the same geographical region (Tehran). The hospital names are shown in Table 3. All selected hospitals are under the supervision of the Tehran University of Medical Sciences. In the evaluation of healthcare centres, selecting efficient inputs and outputs is crucial. In this study, inputs and outputs are selected according to expert opinions and the review of existing literature. In the case study, which included Iranian hospitals, the authors of the article attempted to select indicators that correctly measured the hospital performance.

In this study, the inputs are the number of health workers, the number of other staff, and the number of patient beds; and the outputs are the bed occupancy rate and the bed turnover rate. These indicators are described in Tab. 4.

To measure the hospital performance more comprehensively, 3-year data of hospitals are used. In this study, data on inputs and outputs, including statistical data of the selected hospitals, were obtained from the website of the Statistics Centre of Tehran University of Medical Sciences for the period of 2016–2018. Then, target values were set for the outputs. Selecting the appropriate targets is essential because one of the purposes of this study is to provide a method for improving the performance of health centres. A study demonstrated that the ideal value for the bed occupancy rate was 85%; clinical observations showed that when the bed occupancy rate was greater than 85%, safety and effectiveness of care tasks could be compromised (Keegan, 2010). On the other hand, when the bed occupancy rate is below 85%, it indicates that the resources are used inefficiently. In this study, the ideal bed occupancy rate is set at 85% and this value is considered as the target value for the bed occupancy rate in the DEA-EEP model for all DMUs.

Since the target values of the bed turnover rate are different in specialised and general hospitals, this study does not consider the same bed turnover rate for hospitals, and the ideal value of this indicator for each hospital is determined by experts. Table 5 shows the statistical data of the inputs and outputs as well as the target values of hospitals for 2016. Also, Table 6 shows the data for 2017, and Table 7 — for 2018.

Tab. 3. Names of evaluated hospitals

Hospitals	DMU_s
Imam Khomeini Hospital	DMU_1
Amiralam Hospital	DMU_2
Baharloo Hospital	DMU_3
Bahrami Hospital	DMU_4
Arash Hospital	DMU_5
Shariati Hospital	DMU_6
Razi Hospital	DMU_7
Roozbeh Hospital	DMU_8
Sina Hospital	DMU_9
Ziyaiyan Hospital	DMU_{10}
Children's Medical Centre	DMU_{11}

Tab. 4. Input and output indicators according to the research literature and expert opinion

	Criteria	Description	Author(s)
Input	Number of health workers (C_1)	Number of health workers working in the hospital including doctors, nurses and ...	Liao et al. (2019)
	Number of other staff (C_2)	Number of other staff working in hospital subunits including Food and Drug Staff, Management, Service ...	Chowdhury and Zelenyuk (2016)
	Number of patient beds (C_3)	Numbers of beds specially designed for hospitalised patients or others in need of some form of health care.	Wang et al. (2016)
Output	Bed occupancy rate (C_4)	Calculated as the number of hospital bed days divided by the number of available hospital beds, multiplied by the number of days in a year.	Zhijun et al. (2014)
	Bed turnover rate (C_5)	Number of times that hospitalised patients used a hospital bed over a one-year period	Zhijun et al. (2014)

Tab. 5. Statistical data of hospitals for 2016

Hospitals	Inputs			Outputs		Goals	
	X_1	X_2	X_3	Y_1	Y_2	G_1	G_2
DMU_1	2172	1128	1170	91.02	49.85	85	46
DMU_2	401	232	240	72.83	67.97	85	61
DMU_3	501	156	304	90.05	82.52	85	67
DMU_4	231	110	149	83.34	67.62	85	62
DMU_5	310	118	145	90.60	125.94	85	74
DMU_6	972	563	550	91.36	51.27	85	52
DMU_7	133	90	69	51.32	59.86	85	58
DMU_8	263	154	202	94.26	13.24	85	23
DMU_9	742	398	475	89.58	58.17	85	69
DMU_{10}	294	159	169	86.03	98.30	85	94
DMU_{11}	651	318	370	84.66	53.87	85	68

Source: elaborated by the authors based on (http://sit1.tums.ac.ir, 05.02.2019).

Tab. 6. Statistical data of hospitals for 2017

Hospitals	Inputs			Outputs		Goals	
	X_1	X_2	X_3	Y_1	Y_2	G_1	G_2
DMU_1	2269	1106	1182	91.43	51.89	85	46
DMU_2	416	247	257	73.61	76.92	85	61
DMU_3	539	154	333	81.98	76.02	85	67
DMU_4	239	115	145	78.46	71.90	85	62
DMU_5	339	119	154	96.95	128.19	85	74
DMU_6	1098	603	561	87.48	48.76	85	52
DMU_7	149	90	69	51.94	67.38	85	58
DMU_8	264	185	201	98.41	13.59	85	23
DMU_9	808	418	515	87.76	57.59	85	69
DMU_{10}	296	160	170	82.59	94.83	85	94
DMU_{11}	711	344	393	93.46	76.25	85	68

Source: elaborated by the authors based on (http://sit1.tums.ac.ir, 05.02.2019).

Tab. 7. Statistical data of hospitals for 2018

Hospitals	Inputs			Outputs		Goals	
	X_1	X_2	X_3	Y_1	Y_2	G_1	G_2
DMU_1	2274	1118	1233	88.58	51.57	85	46
DMU_2	421	251	247	73.78	80.64	85	61
DMU_3	542	156	365	76.26	75.31	85	67
DMU_4	240	118	161	71.90	67.77	85	62
DMU_5	347	126	148	88.90	117.13	85	74
DMU_6	1108	607	551	84.07	45.41	85	52
DMU_7	151	94	69	48.26	71.88	85	58
DMU_8	269	189	194	93.29	14.17	85	23
DMU_9	814	424	526	83.15	59.56	85	69
DMU_{10}	298	175	169	74.32	82.32	85	94
DMU_{11}	724	358	408	89.68	66.48	85	68

Source: elaborated by the authors based on (http://sit1.tums.ac.ir, 05.02.2019).

Using the data on inputs and outputs and Model (3), the DEA-EEP model was coded in GAMS software version 24.5.4 and the efficiency, effectiveness, and productivity of each hospital were calculated. Table 8 shows the efficiency, effectiveness, and productivity of hospitals for 2016. Also, Table 9 and Table 10 show these values for 2017 and 2018, respectively. For example, the results of the DEA-EEP model for DMU3 for 2016 are as follow:

The values of the efficiency, effectiveness, and productivity for DMU3 (which is the Baharloo Hospital) are 0.488, 0.979, and 1.467, respectively. μ_5 represents the DMU3 efficiency reference unit. λ_5 and λ_8 represent the DMU3 effectiveness reference unit.

DMU3 should consider DMU5 as a reference unit for the efficiency, and DMU5 and DMU8 Units as reference units for the effectiveness.

Tab. 8. Efficiency, Effectiveness and Productivity scores of hospitals in 2016

Hospitals	Efficiency	Effectiveness	Productivity	μ_j	t_1^-	t_2^-	t_3^-	t_1^+	t_2^+	λ_j	s_1^-	s_2^-	s_1^+	s_2^+
DMU_1	0.070	0.978	1.049	$\mu_5 = 0.568$	0	24.41	12.48	44.07	67.84	$\lambda_5 = 0.327$ $\lambda_8 = 0.651$	0	5.80	0	0
DMU_2	0.406	0.792	1.198	$\mu_5 = 0.646$	0	39.62	26.17	22.15	47.39	$\lambda_5 = 0.510$ $\lambda_8 = 0.282$	0	4.10	0	0
DMU_3	0.488	0.979	1.467	$\mu_5 = 0.790$	54.46	0	67.09	17.75	50.16	$\lambda_5 = 0.617$ $\lambda_8 = 0.362$	0	11.61	0	0
DMU_4	1	0.903	1.903	$\mu_4 = 1$	0	0	0	0	0	$\lambda_5 = 0.494$ $\lambda_8 = 0.409$	0	10.04	0	0
DMU_5	1	1	2	$\mu_5 = 1$	0	0	0	0	0	$\lambda_5 = 1$	0	0	0	0
DMU_6	0.153	0.982	1.136	$\mu_5 = 0.580$	0	35.70	17.64	35.65	63.56	$\lambda_5 = 0.340$ $\lambda_8 = 0.643$	0	11.17	0	0
DMU_7	1	0.632	1.632	$\mu_7 = 1$	0	0	0	0	0	$\lambda_5 = 0.465$ $\lambda_8 = 0.097$	5.90	0	0	0
DMU_8	0.834	1	1.185	$\mu_4 = 0.008$ $\mu_5 = 0.050$ $\mu_7 = 0.281$	0	0	14.23	0	20.95	$\lambda_8 = 1$	0	0	0	0
DMU_9	0.214	0.966	1.180	$\mu_5 = 0.630$	0	30.39	33.65	33.48	63.99	$\lambda_5 = 0.403$ $\lambda_8 = 0.563$	0	23.89	0	0
DMU_{10}	0.758	0.942	1.701	$\mu_5 = 0.050$ $\mu_7 = 0.281$	0	42.20	28.36	0	19.12	$\lambda_5 = 0.403$ $\lambda_8 = 0.563$	0	28.06	0	0
DMU_{11}	0.242	0.913	1.155	$\mu_5 = 0.587$	0	19.61	18.30	29.51	58.85	$\lambda_5 = 0.371$ $\lambda_8 = 0.542$	0	22.15	0	0
Mean	0.501	0.917	1.478	--	--	--	--	--	--	--	--	--	--	--

- t_1^- represents the first input surplus, which equals 54.46;
- t_2^- represents the second input surplus, which equals 0;
- t_3^- represents the third input surplus, which equals 67.09;
- t_1^+ represents the first output deficiency, which equals 17.75;
- t_2^+ represents the second output deficiency, which equals 50.16;
- s_1^- represents the first output deficiency, which equals 50.16;
- s_2^- represents the second output deficiency, which equals 11.61;
- s_1^+ and s_2^+ are deficiencies of the first and second output, respectively, and their values are always zero in this model because it is assumed that the target value is already set to its desired value and cannot be changed;
- t_i^- and t_r^+ are auxiliary variables related to the efficiency and s_t^- and s_r^+ are auxiliary variables related to the effectiveness.

The results of the efficiency evaluation for the period 2016–2018 showed that the efficiency score of Roozbeh Hospital was 0.834 in 2016, but this hospital was fully efficient for remaining years. The efficiency of Ziyaiyan Hospital decreased dramatically over the period. One of the most important issues is the improvement of the efficiency of public health care institutions by changing their legal structure (Lachowska, 2017). Obviously, hospital managers should look for plans to offset this decline. Arash Hospital, Razi Hospital and Bahrami Hospital were also fully efficient during the period. The rest of the hospitals were not fully efficient and had no major changes in their efficiency scores. The efficiencies of these hospitals were fluctuating during this period, and they should look for plans to improve their efficiencies. In addition, the average efficiency of the hospitals during the period was constantly fluctuating.

The results of the effectiveness evaluation for the period 2016–2018 showed that Arash Hospital and Roozbeh Hospital had full effectiveness scores. The effectiveness scores of the rest of the hospitals did not follow a specific trend during the period. Also, the average effectiveness of the hospitals was fluctuating from 2016 to 2018. This shows that the effectiveness of most hospitals did not improve in this period and even declined to some extent.

The results of the productivity evaluation for the period 2016–2018 showed that only Arash Hospital was fully productive. Also, given that the productivity score is the sum of the efficiency score and the effectiveness score, variations of these scores affect the productivity score. Average productivity scores of the hospitals were fluctuating from 2016 to 2018. These results show that the hospitals should seek plans to improve their productivity.

Fig. 2 shows the efficiency scores of the hospitals using the DEA-EEP model. Bahrami Hospital, Razi Hospital and Arash Hospital were fully efficient dur-

Tab. 9. Efficiency, Effectiveness and Productivity scores of hospitals in 2017

Hospitals	Efficiency	Effectiveness	Productivity	μ_j	t_1^-	t_2^-	t_3^-	t_1^+	t_2^+	λ_j	s_1^-	s_2^-	s_1^+	s_2^+
DMU_1	0.073	0.934	1.007	$\mu_5 = 0.566$	0	26.19	12.80	47.17	68.22	$\lambda_5 = 0.342$ $\lambda_8 = 0.592$	0	4.04	0	0
DMU_2	0.418	0.771	1.189	$\mu_5 = 1.265$	3.26	0	31.16	31.76	49.76	$\lambda_5 = 0.581$ $\lambda_8 = 0.175$	1.26	0	0	0
DMU_3	0.433	0.841	1.275	$\mu_5 = 0.697$	54.02	0	72.02	23.42	48.41	$\lambda_5 = 0.564$ $\lambda_8 = 0.278$	0	8.28	0	0
DMU_4	1	0.805	1.805	$\mu_4 = 1$	0	0	0	0	0	$\lambda_5 = 0.532$ $\lambda_8 = 0.273$	0	4.27	0	0
DMU_5	1	1	2	$\mu_5 = 1$	0	0	0	0	0	$\lambda_5 = 1$	0	0	0	0
DMU_6	0.138	0.894	1.031	$\mu_7 = 1$	15.06	0	14.91	39.36	60.84	$\lambda_5 = 0.320$ $\lambda_8 = 0.574$	0	9.62	0	0
DMU_7	1	0.674	1.674	$\mu_7 = 1$	0	0	0	0	0	$\lambda_5 = 0.524$ $\lambda_8 = 0.011$	11.72	0	0	0
DMU_8	1	1	2	$\mu_8 = 1$	0	0	0	0	0	$\lambda_8 = 1$	0	0	0	0
DMU_9	0.201	0.898	1.098	$\mu_5 = 0.600$	0	33.85	37.27	36.10	62.46	$\lambda_5 = 0.396$ $\lambda_8 = 0.502$	0	21.09	0	0
DMU_{10}	0.733	0.850	1.583	$\mu_7 = 1.493$	26.13	0	39.75	8.18	20.96	$\lambda_5 = 0.727$ $\lambda_8 = 0.123$	0	23.29	0	0
DMU_{11}	0.298	0.958	1.256	$\mu_5 = 0.736$	0	33.11	24.55	38.54	67.56	$\lambda_5 = 0.552$ $\lambda_8 = 0.406$	0	14.96	0	0
Mean	0.572	0.875	1.447	--	--	--	--	--	--	--	--	--	--	--

Tab. 10. Efficiency, Effectiveness and Productivity scores of hospitals in 2018

Hospitals	Efficiency	Effectiveness	Productivity	μ_j	t_1^-	t_2^-	t_3^-	t_1^+	t_2^+	λ_j	s_1^-	s_2^-	s_1^+	s_2^+
DMU_1	0.071	0.967	1.038	$\mu_7 = 1.032$	41.46	0	35.76	42.10	69.68	$\lambda_5 = 0.368$ $\lambda_8 = 0.599$	0	3.47	0	0
DMU_2	0.437	0.870	1.307	$\mu_7 = 1.294$	8.62	0	30.41	26.69	53.93	$\lambda_5 = 0.670$ $\lambda_8 = 0.152$	4.07	0	0	0
DMU_3	0.449	0.846	1.296	$\mu_7 = 1.260$	221.24		190.18	2.90	33.39	$\lambda_5 = 0.615$ $\lambda_8 = 0.231$	0	5.87	0	0
DMU_4	1	0.797	1.797	$\mu_4 = 1$	0	0	0	0	0	$\lambda_5 = 0.549$ $\lambda_8 = 0.248$	0	3.08	0	0
DMU_5	1	1	2	$\mu_5 = 1$	0	0	0	0	0	$\lambda_5 = 1$	0	0	0	0
DMU_6	0.129	0.916	1.045	$\mu_7 = 0.927$	19.08	0	15.14	32.67	60.12	$\lambda_5 = 0.315$ $\lambda_8 = 0.601$	0	10.50	0	0
DMU_7	1	0.783	1.783	$\mu_7 = 1$	0	0	0	0	0	$\lambda_5 = 0.614$	14.39	6.29	0	0
DMU_8	1	1	2	$\mu_8 = 1$	0	0	0	0	0	$\lambda_8 = 1$	0	0	0	0
DMU_9	0.201	0.913	1.113	$\mu_7 = 1.119$	32.96	0	53.28	33.37	65.66	$\lambda_5 = 0.453$ $\lambda_8 = 0.460$	0	18.88	0	0
DMU_{10}	0.636	0.829	1.465	$\mu_7 = 1.314$	11.91	0	28.60	10.95	36.33	$\lambda_5 = 0.685$ $\lambda_8 = 0.143$	0	23.89	0	0
DMU_{11}	0.264	0.985	1.294	$\mu_7 = 1.235$	48.29	0	47.09	30.52	67.21	$\lambda_5 = 0.510$ $\lambda_8 = 0.475$	0	18.32	0	0
Mean	0.562	0.900	1.467	--	--	--	--	--	--	--	--	--	--	--

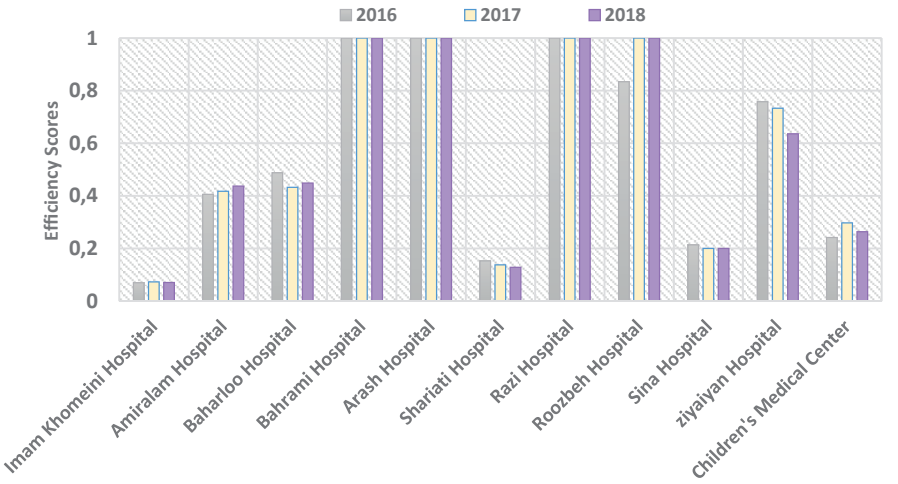

Fig. 2. Efficiency scores of hospitals in the period 2016 to 2018

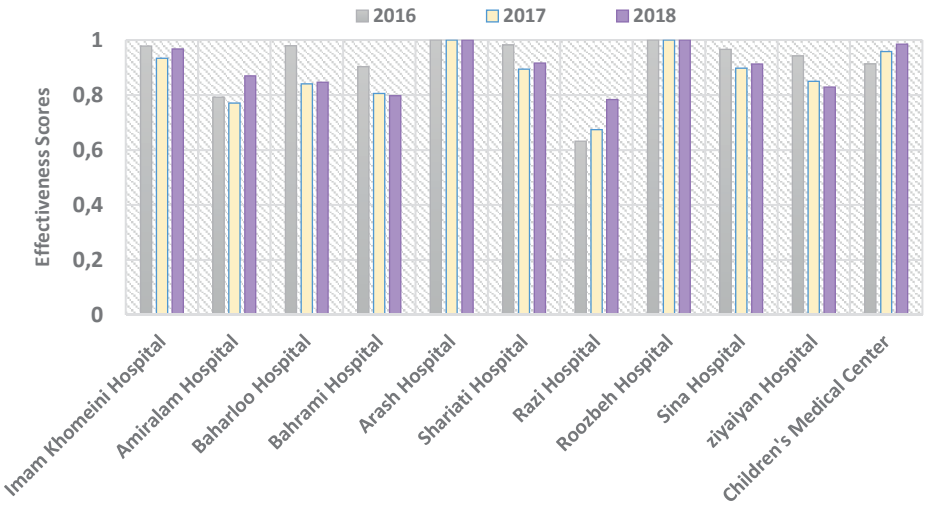

Fig. 3. Effectiveness scores of hospitals in the period 2016 to 2018

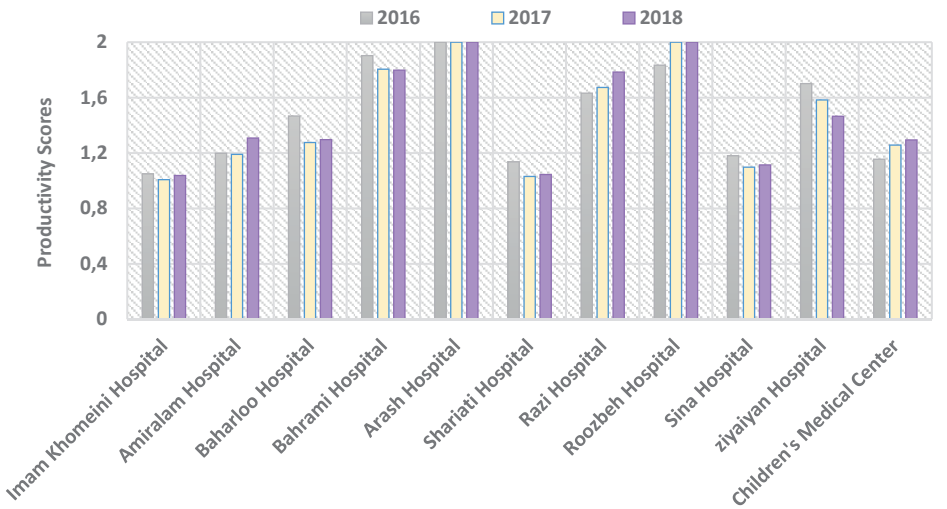

Fig. 4. Productivity scores of hospitals in the period 2016 to 2018

ing the period. Fig. 3 shows the effectiveness scores of the hospitals. Roozbeh Hospital and Arash Hospital were fully effective during the period. Also, Fig. 4 shows the productivity scores of the hospitals. Arash Hospital was fully productive during the period.

4. Discussion

In real-world issues, measuring effectiveness is as important as measuring efficiency. Whenever we talk about effectiveness, we seek to identify the relationship between activities and goals and programmes; when we can better achieve the goals of programmes, we are more effective. So, making a distinction between effectiveness and efficiency is important in performance evaluation. Efficiency measures the ratio of consumed inputs to outputs of a decision-making unit, but effectiveness shows how effective a decision-making unit is in achieving its predetermined goals. In this study, the authors of the article defined effectiveness as the output-to-target ratio. The measurement of the performance of a system based on efficiency and effectiveness can help managers evaluate it in achieving the goals of the system and community. This can facilitate the process of decision-making.

This study has proposed a new model to calculate efficiency, effectiveness and efficiency simultaneously. The model was used to evaluate several hospitals in Tehran in the period 2016–2018. The auxiliary variables of this model were given suggestions for the improvement of the performance of inefficient and ineffective hospitals.

Although some hospitals experienced an upward trend in the period, the efficiency, effectiveness, and productivity scores of most hospitals fluctuated and did not have a growing trend. This indicates that although most hospitals sought to improve the quality of their services, they needed to take more serious steps. Hospitals can review their 2016–2018 performance scores and identify the causes of their strengths and weaknesses; they can use these data to modify inputs and outputs order to improve their future performance. The improvement of staff skills through organisational training, the evaluation of staff and physicians, the review of hospital strategies, and the utilisation of new approaches and equipment in healthcare systems are among the measures that can enhance hospital performance. Therefore, managers and policymakers of the health system in Iran should provide an appropriate context to change the existing situation to improve the efficiency and effectiveness of hospital services.

Conclusions

This paper presented a novel DEA model that can measure the efficiency, effectiveness, and productivity of DMUs simultaneously. The DEA-EEP model can also improve the performance of DMUs by providing a solution to reduce inputs or increase outputs to a certain extent. This model seeks to improve the performance evaluation by using the dual problem with an auxiliary variables-based measure.

The performance of 11 hospitals in Tehran was evaluated using the proposed model. Decision-makers can use the proposed framework to optimally allocate resources, identify reference units, and identify existing strengths and weaknesses of DMUs. In this paper, first, the factors affecting the efficiency and effectiveness of Iranian hospitals were identified based on literature review and opinions of health and treatment experts. Then, data of selected indicators were collected for 11 hospitals.

The results showed that Razi Hospital and Arash Hospital had the highest efficiency, Roozbeh Hospital and Arash Hospital had the most effectiveness, and Arash Hospital had the highest productivity in the studied 3-year period. This paper showed that the DEA-EEP model could be used to rank hospitals in healthcare systems. The results showed that the average of the hospital productivity scores fluctuated in the three-year period and did not follow a specific trend. This indicates that these hospitals need to improve their performance.

Some of our suggestions for future research include: 1) to use one of the MCDM methods for weighting the inputs, outputs, and targets in the DEA-EEP model; 2) to expand the DEA-EEP model using the Network-DEA approach to measure the performance of hospital subunits; 3) to use the DEA-EEP model to evaluate other organisations and activities, such as sustainable or flexible suppliers; and 4) to identify and use other indicators not used in this study for evaluating healthcare centre performance.

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Servitization of manufacturing: survey in the Polish machinery sector

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ABSTRACT

Servitization in developed countries is an increasingly popular strategy for building a competitive advantage. Its level varies depending on different market conditions as well as between sectors. The Polish economy is that of a developed country, but still, its level of development is slightly lower compared to the most developed countries. The current state of knowledge indicates that the machinery manufacturing sector usually characterises the highest level of servitization in comparison to other manufacturing sectors. To the author's knowledge, no study on the servitization of Polish manufacturing companies has been conducted. Therefore, the main objective of this paper is to fill the gap by analysing and evaluating the level of servitization in manufacturing companies operating in the Polish market. Aiming to assess whether the Polish manufacturers follow the global trends of servitization, the questionnaire survey was conducted with 150 machinery manufacturers operating in the Polish market. The survey was performed using the Computer-Assisted Telephone Interviewing (CATI) technique between May and July of 2018. The results showed that in surveyed companies, the level of servitization, which was assessed based on a range of the most frequently provided services, was rather low. Although most manufacturers offer services to their customers, these services mostly support their products, and the revenue derived from the services constitutes a comparatively small part of the company's total revenue. This paper makes two types of contribution to the development of research in the field of servitization. First, the study on the servitization of the Polish manufacturing companies revealed that in a country with the well-developed economy, industrial enterprises still rely on manufacturing rather than service delivery. And the potential for services is not yet recognised. Secondly, the original model for classifying the level of product and service integration in the activity of a manufacturing company is proposed. The model requires empirical verification and further studies. Nevertheless, it stands for a theoretical contribution to the research field of servitization.

KEY WORDS

servitization, product-service systems, product-service integration, machinery sector

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Introduction

The phenomenon called servitization became a fact in the 21st century, and now, it is difficult to discuss it as the world economy is largely based on services. Not only does servitization mean an increase in the importance of the service sector of the economy, but it also describes an increase in the importance of service functions in other sectors (Szukalski, 2004). In particular, and also in industries focused so far on the manufacturing of material products, a change

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into more service-oriented business models may be observed[1]. The effect of these changes is a shift in the focus of whole economies of most highly developed countries towards services or, in other words, towards functional economies. In a functional economy, the object of trade is the usefulness or functionality of a manufactured material product or service. From the manufacturing company's point of view, there are several reasons for such changes. On the one hand, drivers of servitization often come from outside of a company. The change towards servitization may be the answer to client needs or global trends (Goedkoop et al., 1999). Processes occurring in the global economy, as well as the situation on the local market, often force the direction of the development of enterprises. The growing power of customer demands also significantly influences enterprise decisions. In many industries, traditional mass production is changing into the manufacturing of unique products, the composition of which is tailored to specific customer needs (Kovács & Kot, 2016). The functionality of a material product or its availability is a more advantageous and desirable solution, both from the point of view of economy and ecology[2], as well as from the point of view of the customer (Kronenberg & Bergier, 2010; Vezzoli et al., 2014). The concept of sharing economy also brings new opportunities for manufacturers of material products due to the development of digital technologies (Grybaitė & Stankevičienė, 2018). In consequence, services gained more importance as a crucial component of the final offer of manufacturing companies.

On the other hand, the idea of and the need for change arise inside the company. Building innovative strategies and evaluation of the business model determine the development of the company (Dębkowska, 2017). Thus, to seek and create new strategic possibilities, companies systematically evaluate their resources and capabilities in terms of improvement and development. Identification of a new alternative way to satisfy a customer by anticipating the emergence of new needs allows building strategies which ensure long-lasting competitive advantage and develop new innovative business models. Also, new strategic possibilities may be identified by a comprehensive analysis of the environment (from a micro and macro perspective). The analysis of the environmental conditions by increasingly popular future-oriented methods (e.g., foresight analysis methods[3]) helps to identify trends and opportunities in the nearest or a more distant environment. Expanding the offering portfolio with additional services, offering a bundle of products and services, or even replacing the sales process with leasing, renting or sharing the product for a certain period, allow the manufacturing company to gain: (i) new customers for whom the product price is a purchase barrier, and (ii) to strengthen the relationship with the existing customers (Mont, 2002). For a number of manufacturing enterprises (e.g., IBM, Royce Rolls or Xerox), the change towards a new business model based on the provision of services was an extremely successful strategic choice (Kozłowska, 2015).

The scope and scale of servitization vary both within the sector and across countries. The Polish economy is that of a developed country, but still, its level of development is slightly behind the most developed countries. Predictably, manufacturing companies are in the initial stages of change towards servitization, which is already more noticeable in highly developed countries. But to the author's knowledge, no such study has been conducted in Poland, which indicates a research gap. Consequently, one of the objectives of this paper is to analyse and evaluate the level of servitization in manufacturing companies operating in the Polish market. This study focuses on the manufacturing sector of machinery and equipment, in which the acquisition of goods creates a bond between a customer and a seller or a manufacturer, which lasts for several years through warranty or maintenance services. This encourages producers to enrich product offerings with complementary services or make further steps into servitization. A pilot study conducted by the author in 2016, covering the analysis of offers (in generally available catalogues, documents, and websites) of 100 enterprises operating in the Polish machinery sector, showed that the vast majority of entrepreneurs had at least one type of service in the offer (Kozłowska, 2017), and less than 10% of the

[1] The share of the added value generated by the service sector in some countries reaches almost 90% of the total added value of a given country (Luxembourg — 86.9%, Malta — 85.1%). In Poland, it has been about 60% of GDP for several years, for example, in 2017, it was 63.9% of GDP (Rynek …, 2018).

[2] The inclusion of services in the offerings of companies from the industrial sector results in the more effective use of products manufactured with more optimal use of materials and energy consumption throughout the product life cycle (Kronenberg & Bergier, 2010).

[3] Application of different foresight methods in the environment analysis can be found, for example, in works by Nazarko et al., 2017a; Nazarko et al., 2017b; Nazarko & Kononiuk, 2014; Kononiuk & Magruk, 2015; Szpilko, 2014; Ejdys et al., 2019; Gudanowska, 2014.

sampled enterprises offered broad packages containing more than six types of services. Few entrepreneurs of the Polish machinery sector integrate service functions with manufactured products. At the same time, only occasionally, 3% of the surveyed sample focus their activity exclusively on the manufacturing of products. Then, it can be assumed that service provision will be gaining more importance in Polish industrial sectors, as it happens in other countries that have more developed economies. It seems interesting whether the level of servitization differs significantly from other markets. The results of this study should provide an answer to this question. During the literature studies, the other research gap was identified. No model for assessing the level of servitization of companies based on quantitative research results has been found in the literature. Usually, such level is evaluated based on the results of the case study or other qualitative research methods. The author proposes an original model for classifying the level of product and service integration in the activity of a manufacturing company, which may be used for data gathered in the surveys.

The paper is structured as follows. The first part of the article presents the results of the literature review connected to the main concept of the integration of products and services in manufacturing as well as the scope of this phenomenon in different countries and markets. Then, the research methodology of this study is described. The author conducted a survey of the Polish machinery manufacturers using the CATI technique and a few in-depth interviews with experts within the servitization field. Then, the research results related to the level of the product and service integration are presented. The last part of the paper summarises the obtained results, explains the limitation of the study, and indicates the directions for further research.

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1. Literature review

The idea of integrating material products with services emerged against the background of the concept of sustainable development and circular economy as well as related research trends and as a result of changing market conditions. Technological progress and the globalisation of the economy have intensified competition, especially in emerging economies, where production costs are much lower compared to highly developed countries. According to research by Wu et al., US manufacturing companies would have to cut their production costs by 30% to compete with Chinese manufacturers (Wu et al., 2006). Moreover, the competitive impasse caused inter alia by the declining rate of return on long-term continuous investment in product innovation, which key industrial players can quickly see and copy, does not offer an opportunity to build a strong competitive advantage in the long term. As a result, in some markets, such as computer hardware, software, medical devices, and capital goods, a decreasing variety of product offerings can be observed (Shelton, 2009). The search for new instruments of competitive advantage is also driven by the decreasing demand for traditional industrial products and the short-term nature of technological novelties (Payne, 1996). In such a highly competitive environment, many companies face increasing uncertainty about income streams and volatility in input prices. The ease of production in low-cost countries and increasingly severe environmental regulations are just some of the factors that impede the functioning of markets. The development of the operational capacity to meet these challenges is crucial to improve the competitiveness of industrial companies. In response to market challenges, manufacturing industry leaders are increasingly complementing their product offerings with innovative services that increase the overall value for customers. Services are experiences rather than things (Jarocka & Wang, 2018). Therefore, personalised offerings, which include a wide range of services and allow creating new customer relationships as well as building a stable competitive position, are much more difficult to copy and imitate by competitive companies than innovations in production technology.

The phenomenon of product–service integration is closely related to such research fields as product–service systems (Goedkoop, 2004; Mont, 2004; Tukker, 2004) or industrial product–service system (Meier et al., 2010), servitization (Neely, 2007) or servitization of industry/manufacturing, service–oriented products (Tan, 2010), hybrid offerings (Ulaga & Reinartz, 2011), product–service offerings (Gaiardelli et al., 2014), integrated solutions (Shelton, 2009) or product/service solutions (More, 2013), but also as eco-efficient services, functional sales or a functional product (Tan, 2010). Concepts behind

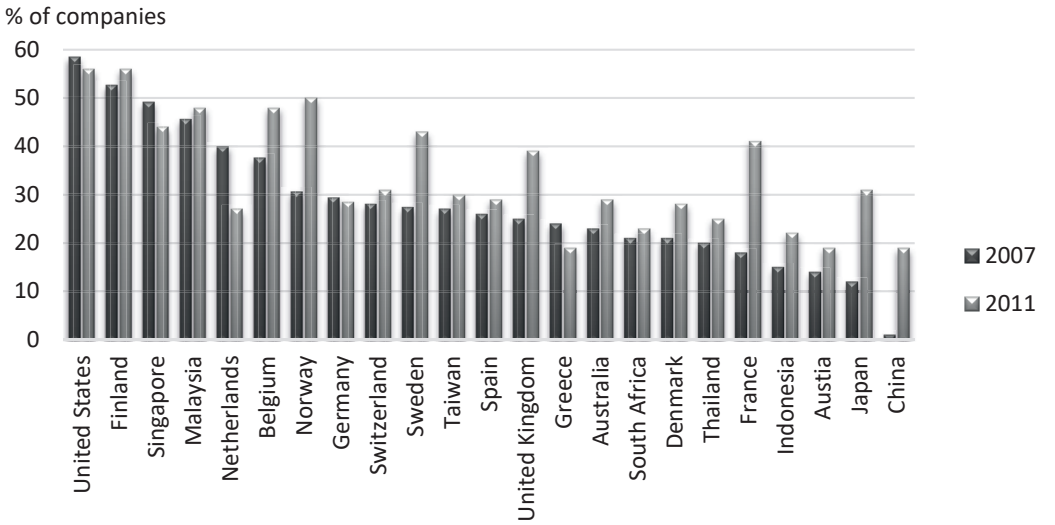

Fig. 1. Percentage of manufacturing companies with an integrated product and service offerings
Source: elaborated by the author based on (Neely, 2008; Neely et al., 2011).

these terms often have the same background and ideas, while differing only by details. However, the most common terms that have appeared in the scientific literature for several years were "servitization of industry/manufacturing" and "product-service systems (PSS)." It should be mentioned that some researchers treat these terms as synonyms (Paslauski et al., 2016; Lightfoot et al., 2013) or elements of the same concept[4]. Servitization may be defined as offering market packages or "bundles" of customer-focussed combinations of goods, services, support, self-service, and knowledge, in which services begin to dominate (Vandermerwe & Rada, 1988). Product–service systems are the most advanced solutions, which are understood as an integration of tangible products and intangible services into one solution/system to jointly satisfy customer needs (Goedkoop et al., 1999). The servitization, however, starts with extending a product offer with complementary services, which are product-oriented. Afterwards, use-oriented and, finally, result-oriented services are proposed to clients (Tukker, 2004). In this way, as a result of the servitization process, services substitute the sale of the physical products and are immanently joined with the product in one offering/solution delivered to clients.

The literature review conducted by the author showed that the studies analysing the phenomenon of industry servitization were undertaken in many countries around the world. In the area of servitization and PSS, qualitative research predominates with case studies being the most commonly used technique[5]. Quantitative studies that allow the analysis of trends and the progress of servitization processes as well as their scope in various industrial sectors in different countries or globally were undertaken by several authors (Qu et al., 2016). Quantitative surveys on large samples (dozens or more) are limited and usually carried out as part of large international servitization projects or conducted on data retrieved from thematic databases and public reports.

The results of the research by Neely on a global analysis of trends in the manufacturing sector in 2007 are among the most frequently quoted in literature. Neely analysed over 12 000 enterprises employing over 100 employees and operating in the manufacturing industry, catalogued according to US SIC codes 10 – 39 (from the extraction of metals to the production of various types of products). Data for the study were taken from the OSIRIS database. The percentage of producers, qualified by Neely to the group that offered integrated product and service solutions, according to data from 2007 and 2011, is presented in Fig. 1. The researcher also identified 13 forms of services offered by production companies, distinguishing the following types of services: consulting, design and development, financial, installation and implementation services, leasing, maintenance, and technical support, outsourcing and service, organisation of procurement, management and real estate trade, distribution, transport solutions and transport services (Neely, 2007).

[4] According to Baines et al., PSS are a special case (stage) of the process of servitization (Baines et al., 2007).

[5] Among 2 267 publications related to servitization and product and service systems in the found in the WoS database, 546 (around 24%) were case studies.

Neely's research demonstrated that services were offered by approximately 30% of global manufacturers that have more than 100 employees. In addition, there was a clear correlation between the servitization of the manufacturing sector and the level of development of the local economy as highly developed economies generally had more manufacturing companies offering integrated products and services compared to industrialised countries. Moreover, the total revenues of enterprises that offered both products and services constituted the major part of all revenues in the studied sample while representing a much smaller group of companies. Among the largest corporations, relatively more offered integrated services than those dealing exclusively with the production of goods, and revenues from services for many companies showed relative stability over the years. Noticeable is an increase in the percentage of manufacturers in China who provide integrated product–service offerings. It has risen from less than 1% (in 2007) to around 20% (in 2011). Such significant and rapid change may indicate that producers from China want to step out of the role of a global manufacturing base, focusing on manufacturing activities with low added value, and follow global trends in servitization (Neely, 2008).

Research conducted in Europe within the T-REX project (Lifecycle Extension Through Product Redesign and Repair, Renovation, Reuse, Recycle Strategies for Usage & Reusage-Oriented Business Model) in 2007–2013 with 95 European manufacturers of machines, means of transport and automatic devices revealed that the vast majority of the income of the surveyed manufacturers came from the sale of products. Service provision generated only about 12% in the machinery and automatic equipment sector and about 40% in the transport manufacturing sector. In addition, the survey results showed that advanced services, such as leasing, rent, warranty extensions, renovation and maintenance contracts, were rare and sometimes ignored by the industry (Adrodegari, 2015).

Above-described research was international. Many researchers undertake analyses of the servitization processes in local markets.

According to research by Crozet and Milet on the French market, 83% of companies registered in the industrial sector provided services to third parties, and nearly one-third of these producers sold more services than goods. The survey covered a relatively large sample of more than 635 000 French manufacturing companies, whose share of the revenue from the provision of services in the total sales changed by more than 11% between 1997 and 2007. This percentage increased steadily over the analysed period by more than 10% between 1997 and 2001, and by almost 3% between 2003 and 2007. However, two-thirds of manufacturers derived less than 20% of their incomes from services. At the same time, around 30% of French manufacturers derived over 80% of their income from service provision. The authors concluded their research work by stating that the servitization of the French manufacturing sector was driven by the dynamics of the development of enterprises and not by the sector in general (Crozet & Milet, 2017).

In 2012, a study carried out in Spain by Santamaria, Nieto and Miles showed that almost 20% of the surveyed companies innovated their activity by adding new services. Spanish manufacturing companies showed that sectors using advanced technologies, including both machinery and information technologies, also had more service innovation than sectors using medium-advanced technologies (Santamaria, Nieto & Miles, 2012).

The research conducted by Neely on a large sample of 4067 German manufacturing companies revealed that 25% of them could be classified as servitized. The authors analysed enterprises having more than 100 employees. The level of servitization was assessed based on the text analysis of "business description" in the Capital IQ database. The data suggested that the highest servitization level was represented by industrial sectors (around 40% of the research sample), from which the construction and engineering industry seemed to be most highly servitized with 56.30%. The next highest level of servitization was observed in the sectors producing construction and farm machinery (50.88%), heavy electrical equipment (49.25%), aerospace and defence (49.09%), and industrial machinery (42.37%). The author also showed that the levels of servitization increased with firm size. Over 40% of the largest German manufacturing firms were servitized (Neely, 2013).

Huxtable and Schaefer published the results of a UK study in 2016[6]. Around 75% of analysed manufacturing companies derived less than 40% of their revenues from services, which, in the light of the literature studies carried out by the authors, led to the conclusion that there were still opportunities

[6] The research included the analysis of generally available documents and reports of 57 companies operating in the UK.

and the developmental potential in the field. Moreover, they argued that the Industry 4.0 concept was related and/or influenced the servicing processes. It is possible to benefit from offering Industry 4.0 services, but attention should be paid to the existence of significant economic risk factors that are related to the difficulty in estimating the costs of providing services in the long term (Huxtable & Schaefer, 2016).

In 2016, studies on servitization were also carried out in Italy[7]. On average, 37% of medium-sized manufacturing companies in Italy offered different types of service components. The size of the company corresponded with the percentage of integrated offerings, i.e., the bigger the company, the higher the percentage. Also, the highest level of servitization (measured in terms of the size of the range of services offered and their nature) was observed in the machinery and metalworking sectors (Mastrogiacomo et al., 2017).

Danish researchers Raja and Frandsen noted that most analyses focused on servitization strategies in the western part of the globe, among companies operating in developed economies. Therefore, Raja and Frandsen conducted a case study on a Danish manufacturer of capital goods who had intensively developed its operations in the Chinese market through a subsidiary. The survey consisted of 22 interviews conducted at the company's headquarters and in its Shanghai branch, with employees at various levels of manufacturing and service delivery. According to Danish research, the implementation of service strategies requires the organisation of a network of cooperation with local partners. One of the key aspects of servitization is to establish and maintain appropriate relationships with customers, which can only be ensured by cooperation with local partners who have knowledge of the local market and customers. The offering of advanced services and solutions often requires additional investments in the development of the skills of external partners (Raja & Frandsen, 2017).

Just recently, the study on service innovation and servitization has been carried out in Japan. It showed that the degree of servitization differed significantly across industries. The highest level has been observed in the transportation machinery industry (approx. 1.6%), while in the leather industry there were no signs of servitization. In general, the servitization ratio is high in the processing assembly industries, which have closer contacts with end consumers. The material industries (providing industrial materials, etc.) represent relatively low degrees of servitization (Shikata et al., 2019).

Based on the above literature review, it can be stated that in many countries and markets, the servitization processes are visible, but to a somewhat different extent. The scope of servitization also differs between sectors. In industries, such as machinery manufacturing, metal processing, automotive or high-technology industries, services are more common and more advanced than in in the clothing industry, for example. However, it is difficult to compare research results from different markets as they were conducted on a different scale (the chosen sectors or in manufacturing companies generally), with different research methods (analysis of data available in reports and databases or data obtained in interviews and surveys), assumptions or limitations. Nonetheless, no such study has been conducted in Poland. This was the main prerequisite to undertake the research of the Polish market in the context of servitization. Its results are presented in the following sections of this article.

It should be noted that most studies described above were conducted using data derived from different databases. Companies were classified as servitized mainly on the basis of the description of the business activity mentioning services as a part of it or if the company reported that some share of the total revenue came from services. In the author's opinion, both aspects (service offer and the share of income from service in the total income) should be considered while evaluating the progress of the servitization in manufacturing. Therefore, an original model for classifying the level of product and service integration in the activity of a manufacturing company was developed and described in the third part of this paper.

2. Research methods

The survey was carried out in May–July 2018, using the Computer-Assisted Telephone Interviewing (CATI) technique and a structured questionnaire as a tool. The CATI technique was chosen because of its advantages, including the continuous monitoring of the survey and the quality of the collected data, the short time needed to conduct interviews, the possibility to directly record data in an electronic form, the standardisation of telephone interviewing techniques,

[7] The survey was carried out on a relatively large group of more than 9 000 medium-sized Italian production companies using textual analyses of the companies' activity descriptions available in the AIDA database.

and the minimised risk of errors and data gaps in final results. The obtained data allowed to assess the level of servitization in Polish machinery manufacturing companies. Due to the exploratory aim of questions, nominal and interval scales were used. To measure the frequency of service delivery by a company, a 7-point Likert scale was applied. Telephone interviews were conducted among managers or other decision-makers in 150 enterprises operating in the Polish machine and equipment manufacturing sector. According to the data of the Central Statistical Office (GUS), section 28 C (industrial processing) has the total of 9595 registered economic entities (BDL, 2017). The size of the research sample was set at 150 due to the financial feasibility as well as technical and organisational possibilities. It is increasingly more difficult to convince entrepreneurs to participate in full telephone interviews, especially considering a limited timescale. A random selection of respondents and the size of the selected statistical sample allow generalizing conclusions for the entire population of machinery and equipment manufacturers with a maximum error of 8% at a confidence level of 95%. The study results were also discussed with several experts with academic and business experience in servitization. Experts from the academic environment had at least several years of experience in observing and analysing the economic situation on the Polish market, and, in particular, in the industry sector. The business environment experts represented a medium or large enterprise, which offered a varied scope of services to clients, performing managerial functions in their organisation and having a minimum of five years of experience in the industry. The purpose of qualitative research was to confirm the results of quantitative research and to deepen the knowledge about the reasons for taking up service activities by manufacturing companies and factors influencing the process of servitization in Polish enterprises.

3. Research results

The surveyed enterprises were located throughout Poland. Each province (voivodship) was represented by at least three respondents. Among the surveyed machinery and equipment manufacturers, more than half in terms of size, measured by the number of employees, were medium enterprises (52%). The next largest group (27%) were small enterprises employing from 10 to 50 employees. Manufacturers employing more than 250 employees constituted 19% of the surveyed sample, while those qualifying as micro enterprises, i.e. employing less than ten people, constituted only 2% of the surveyed sample.

The basic part of the questionnaire was questions related to the service provision. According to the survey results, over 80% of machine and equipment manufacturers offered their customers services related to their products (Fig. 2). Around 13% delivered services unrelated to the manufactured products. Only 5% of companies did not perform any kind of service to their clients.

Within the framework of the research, the assessment focused on the scale of the frequency of the use of different types of services. This part of the questionnaire was filled in only by entrepreneurs providing services related to manufacturing (i.e., 123 respondents). Based on the pilot study conducted by the author in 2016 and the literature review, a catalogue was prepared to list 16 services provided by entrepreneurs operating in the sector of machinery and equipment manufacturing. The catalogue of services included: pre-sales consultations, financial support (loans, instalments), transport, assembly and/or implementation, training and technical advice after the sale of products, warranty after-sales service, post-warranty after-sales service, maintenance and technical support, modernisation, repairs, regenera-

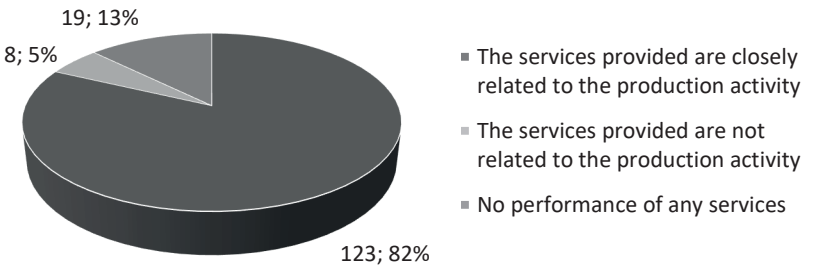

Fig. 2. Structure of the research sample in terms of services delivered

tion, disposal, scrapping and/or recycling of waste product (equipment/machinery), monitoring, research, expertise, rental, leasing and a vast range of so-called industrial services (machining, milling, cutting, bending etc.). During the interview, respondents were asked to assess the frequency of providing certain forms of services on a scale from one to seven, where one meant that the given services were "not provided by the manufacturer at all," while seven meant that they were provided "very often (several times a month/daily)." The results are presented in Table 1. In the machinery industry, the standard services were warranty and post-warranty. Over 80% of the respondents had this type of service in their offer, and over 75% carried out warranty service activities several times a month. Almost as frequently, customers of the surveyed enterprises (76%) used the consultation service to adjust the product to their needs and even to design machines or devices in detail. A relatively large group of manufacturers (70%) provided maintenance and technical support services for their products. Due to the machinery park, manufacturers used the potential of their production halls through the implementation of industrial services, which included such services as cutting, bending, milling, machining, and other methods. Over 60% of the surveyed companies provided these services very often. Among the least frequently offered forms of services were leasing, financial support in the form of credit or instalment payments and rental of machines. Additionally, producers also indicated the following services as relatively frequently provided and not included in the questionnaire: design, 3D modelling and visualisation, start-up of the production line, logistic services (supply, storage, storage, warehousing, completion of deliveries), audits, testing and risk analysis and construction office outsourcing.

In terms of the revenue from the provision of services, the largest group of respondents (52%) declared that the income constituted less than 15% of the total revenue, and another 17% reported the revenue share from services of 15% to 20%. The other surveyed producers (about 30%) achieved more than

Tab. 1. Frequency of services provided by the surveyed manufacturers of the machine industry

Service type	Assess on a scale from 1 to 7, how often these services are provided, if: 1 – Means that these services are not provided at all in the company, 7 – Means that these services are provided very often (several times a month/daily) percent [%]							
	1	2	3	4	5	6	7	sum
Warranty after-sales service	19	2	3	1	3	23	49	100
Post-warranty after-sales service	22	1	2	1	5	22	47	100
Pre-sales consultations	24	3	3	3	7	15	44	100
Maintenance and technical support	30	0	3	6	11	19	31	100
Industrial services (machining, milling, cutting, bending and other manufacturing services)	30	3	1	2	11	20	33	100
Modernisation, overhauls, regeneration	35	3	5	4	17	21	15	100
Assembly and/or implementation	36	1	2	6	9	23	23	100
After-sales training and technical advice for products	39	5	1	4	18	15	17	100
Transport	42	5	5	3	9	19	17	100
Research, expert opinions	59	4	5	8	7	13	4	100
Disposal, scrapping and/or recycling of waste product (equipment/machinery)	70	3	1	5	12	7	3	100
Monitoring	74	2	3	2	8	3	7	100
Maintenance	79	4	2	5	5	3	2	100
Rental	89	3	2	1	3	0	2	100
Financial support (loans, instalments)	91	1	3	2	1	1	1	100
Leasing	92	3	1	1	3	1	0	100

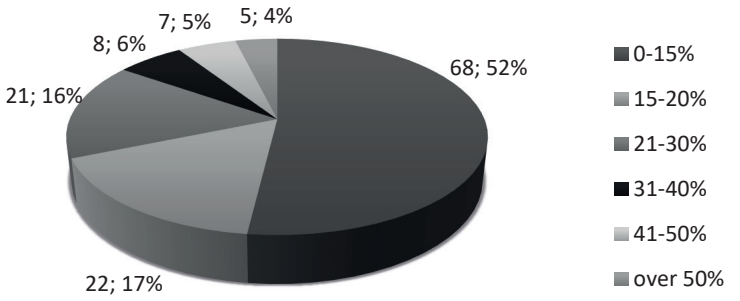

Fig. 3. Share of revenues from the provision of services in total revenues

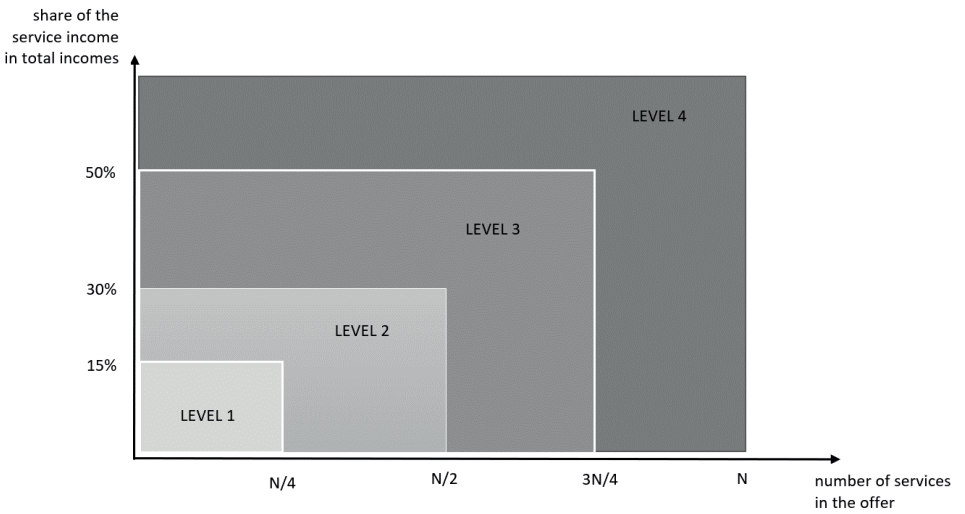

Fig. 4. Original model for classifying the level of product and service integration in the activity of a manufacturing company

20% of their revenue from the provision of services, and the highest percentage of revenue from services in the total revenue of the company (i.e. more than 50%) was shown by only 4% of surveyed producers who had production-related services in their offer (Fig. 3). In this case, the percentage shares refer to all producers providing services, including those unrelated to the manufacturing activity, i.e. 131.

Judging from the results of the analysis into service offers by Polish machinery and equipment manufacturers, the main focus is on the provision of services complementary to the manufactured goods. These are services characteristic for the first steps of servitization. Services characteristic for more advanced service providers within the manufacturing sector include the following from the analysed set: research and expert opinions, disposal, scrapping and/or recycling of waste product (equipment/machinery), monitoring, maintenance, rental, and leasing. These are located at the bottom of Table 1, which is sorted according to the decreasing frequency of services provided by Polish machinery and equipment manufacturers. For each of these services, less than 25% of the surveyed companies (and for some, it is only a small percentage) reported the provision of these services with a frequency higher than a few times a month. On the other hand, over 60% (and in some cases, even about 90%) of the surveyed enterprises claimed that there were no such services in their offer. Therefore, it can be concluded that the Polish machinery industry still mostly has the basic model of servitization, in which the services provided constitute a complementary part of the offer and are mainly centred on the material product. More advanced models, including services substituting product acquisition, such as leasing or rental, or requiring a higher level of customer interaction, such as monitoring or maintenance, are rarely used on the Polish machinery market. Around 70% of surveyed companies reported that the share of revenue derived from service provision as at the most 20% of the total revenues of the firm. This also indicates that the machinery manufacturers in Poland still focus on manufacturing and the service provision is rather additional and occasional.

To evaluate the level of servitization of surveyed companies based on collected data, the following model for classification is proposed. Scientific literature suggests no model for such classification, which would be applicable to the quantitative research results. The model (Fig. 4) assumes that the level of product and service integration can be measured using two dimensions:

- the percentage share of the revenue from services in the total revenue;
- service catalogue described by the number of services in the company offer, assuming the maximum number of N services identified for a given industry.

The number N of different types of services in the offering should refer to the specifics of the industry and include the maximum number of services identified for the examined industry. The first dimension — the percentage share of the revenue from services in the total revenue — is rather a popular measurement (used, e.g., by Shelton, 2009). In the model, the following thresholds of the share of the service revenue are set: 15%, 30%, 50%, and more. And for the second dimension — the number of services in the company offer — one can assume the achievement of the next level of advancement when expanding the service offer by the number N/4 services (step: 25%), where N is the maximum number of services identified in the offers of enterprises of a given industry.

For the machinery industry, 22 types of services were identified, i.e., 16 types of services were assessed in the questionnaire, and six additional types of services were proposed by the respondents. The classification of each object was carried out for two dimensions separately, and ultimately, the company was classified based on the higher result of the classification. Due to the model assumptions, it should be noted that the results are an optimistic rather than a pessimistic version of the actual level of servitization of machinery industry enterprises. Half of the companies represent the second level of servitization, while the highest level was reached by 3% of the surveyed manufacturers. Producers who were a part of this small group, showed high shares of the revenue from services, with a range of about 11 forms of services.

Since many researchers indicate a correlation between the servitization level and the size of the company (e.g., Mastrogiacomo et al., 2017; Neely, 2013), a contingency table was created for the two features (Table 3). It can be noticed that levels 1 and 4 are represented only by small and medium enter-

Tab. 2. Level of product–service integration of the surveyed enterprises according to the authors of the classification model

Level	Characteristics of the level settings	Number of companies	Percent [%]
1	Number of services <6 and the share of the service income in the total income below 15%	11	7
2	Number of services between 6 and 11, or the share of the service income in the total income between 15% and 30%	76	51
3	Number of services between 11 and 17, or the share of the service income in the total income between 30% a 50%	39	26
4	Number of services >17, or the share of the service income in the total income more than 50%	5	3
Beyond qualification	No services in the offer	19	13

Tab. 3. Contingency table of two variables: the company size and the level of servitization

Level of servitization	Company size (measured by the number of employees)				
	micro	small	medium	large	sum
Level 1	0	6	5	0	11
Level 2	1	20	40	15	76
Level 3	1	5	23	10	39
Level 4	0	3	2	0	5
Beyond classifiaction	1	6	9	3	19
Total	3	40	79	28	150

prises. Level 2 and 3 are dominated by medium manufacturers (over 52% and 58% of companies at a level, respectively).

At the same time, it is visible that all large companies represent level 2 or 3 of the product–service integration. The distribution of results for small and medium manufacturers is dispersed more. It may also be observed that small companies represent a lower level of the product–service integration in their activity. However, no clear correlation is suggested by these data. For the two variables, a chi-square test was also performed, to analyse the relationship between them, and no statistically significant relationship was found (p=0.26, chi-square=14.63 with df=12).

4. Discussion of the results

The survey results indicate that over 80% of Polish machine and equipment manufacturers offer their customers services related to manufactured products. This is a relatively high level compared to the global results received by Neely in 2007, which indicated that about 30% of producers with more than 100 employees offered services, or the results received by Italian researchers Mastrogiacomo, Barracecchia, and Franceschini in 2016, according to which about 37% of medium-sized manufacturing companies in Italy offered various types of service components. It should be noted, however, that in both cases, research was carried out in companies with different types of manufacturing activity, and the Italian researchers noted that the machinery and metal processing sectors were characterised by the highest level of servitization, measured by the range of services offered and their nature. On the other hand, the results of the research obtained by the author in relation to the results obtained by Crozet and Milet for the industrial sector in France show a very high degree of similarity in terms of the service activities in these markets. In the French market, more than 83% of companies registered in the industrial sector also provided services. Therefore, this result is almost identical to the one obtained by the author during the survey among Polish manufacturers of the machinery industry. It also turns out, that services are not a novelty among Polish machine manufacturers as the vast majority of surveyed enterprises (67% of all providing any services) has been providing services since the beginning of their existence in the market. At the same time, even if services constitute an additional offer diversifying the company's activity and were already introduced during its operation in the market, they have been implemented in enterprises for over a dozen years. Among those producers who provide services, the vast majority has comparatively lengthy experience with this activity. Almost 80% have been providing services for over 15 years, and only 5% did so for less than five. But these are still mostly product-oriented services. So, the potential of more advanced services or service-oriented business models has not yet been recognised by Polish manufacturers. However, it can be observed that in general, the Polish market has been developing in recent years rather rapidly, and entrepreneurs usually try to compete with companies from around the world. According to the results of the Mitsubishi Electric Europe report, the machinery sector is one of the most innovative industries. Polish manufacturers in competition with producers of cheap industrial machines manufactured, for example, in China, offer such services as financing of purchases in cooperation with leasing funds, good service warranty, and post-warranty, the possibility of extending product life-cycle and renovating machines (Kołaczek, 2018). Therefore, it may be assumed that the servitization level of this sector will be rising in the nearest future.

It seems positive that a small percentage of enterprises represents level 1 of servitization, and a quarter of the sample (26%) reaches level 3, i.e., generates over 30% of the revenue from the provision of services or expands the range of services and has several types of services in the offer. This may indicate that entrepreneurs see potential in service provision and decide to develop in this direction. It is obvious though that in general, the service provision by Polish machinery manufacturers is still a secondary source of income in relation to production.

The study results were presented and discussed with experts, who have either academic or business experience in the servitization field. They pointed out that the Polish market reacts to global trends with some delay. In terms of economic structure and technological level, it differs slightly from highly developed countries, in which servitization reaches higher levels of maturity:

Expert 1: "(...) First of all, in Poland, we have a dominant agricultural sector, and the industrial sector probably generates about 30% of employment. Secondly, we still have large resources in Poland when it comes to so-called cheap labour. We have a lot of production workers (...) That is why, I think, we have quite a gap to fill in comparison to most developed

countries." Although experts see the product–service integration signs in the Polish industry:

Expert 2: "... the importance of production compared to services in Poland is generally higher than the statistical average in more developed countries (...) which is probably the result of a certain delay related to the economic transformation, as well as the geographical location of our country. Despite this, there are visible signs of following global trends. Currently, the potential of service activities and the process of servitization in Poland is beginning to be recognised among Polish enterprises, especially in certain industries and among younger managers."

Expert 3: "It is more observed in some industries, less so in others, but companies are beginning to pay attention to it."

Thus, the servitization trend may not be exploding now among Polish machinery manufacturers, but it is progressing and expected to increase in the future.

Conclusions

In the 21st century, services and the service sector gained greater importance which is also reflected by the growing attention to service functions in the industrial sector. In the framework of the study presented in this paper, the research review was conducted. It mainly focused on European efforts and showed that the level of servitization varied in different countries and different sectors of a country. The most prone to servitization was the machinery and metalworking industry as well as those industries that mostly relied on information technologies. The results of the survey conducted under the Polish market conditions showed that machinery producers focused more on manufacturing than on service provision. Although the vast majority of them performed services for a rather long time, these were mainly warranty and post-warranty after-sales services, pre-sales consultations, maintenance, and technical support and industrial services (machining, milling, cutting, bending and other manufacturing services). And the potential for more advanced services, which were use-oriented or result-oriented, was not yet recognised. The latest reports on the state of the machinery sector outlined the continuous improvement of the quality of cheaper industrial machines manufactured, e.g., in China. Thus services, especially those that substitute the purchase of products, are likely to be of greater interest for manufactures and the servitization process will continue.

Obviously, the major limitation of this study is the range of the research — the survey targeted Polish manufacturers representing one certain sector. It means that it cannot be representative of the whole industry in Poland. The second limitation is the original model that was used to assess the level of product–service integration in surveyed companies. Though it seems to be constructed similarly to other methods and models for measuring the level of servitization, it is experimental and lacks an empirical verification. The share of the service income in the total income of the company was surely the most popular and widely recognised measurement of servitization in a manufacturing company, but the other dimension — the number of services and, in particular, its thresholds — needs to be verified and adjusted to the sector. In some cases, a low number of services means that the company specialises in its delivery or services are so deeply integrated into the offering that their components are difficult to separate or be counted, so in fact, the threshold may be much lower than it was assumed in the model.

Therefore, this study raises at least a few questions for further research: Whether and to what extent servitization processes occur in other Polish manufacturing sectors? What are the reasons behind the low level of product–service integration in Polish machinery manufacturing companies? Is it the reluctance of the customers or the lack of the need? Or could it be that manufacturers lack competencies in delivering more advanced services? Should the increase of the servitization level be expected in all industry sectors in the coming years? Likewise, the empirical verification of the proposed model for the classification of product–service integration seems to be a promising field for future research.

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Investigation of the influence of product variety on inventories in hospitals

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ABSTRACT
The literature on product variety provides great insights into various businesses. However, little research has been conducted on product variety in the healthcare industry. This study aims to explore the influence of product variety on inventory in hospitals. Since most hospitals are known to replenish products using a homegrown ad-hoc system, a model is developed for exploring all possible product combinations and substitutions. This article presents the behaviour of product substitution, which may be either one-to-one or many-to-one for both sterile and non-sterile products, in the hospital with cost factors. It discusses the product variety reduction and its corresponding cost impacts. The data on a hospital inventory over the course of six years has been procured from a hospital in Norway. Based on the results, the hospital could have a potential product variety reduction of approximately 11% and cost savings from the spending of approximately NOK 3.6 million. Reducing the variety of products in hospital inventories proves to be an approach to reducing costs. The model developed for the research is universal in nature and could be used in other fields, such as retail, marketing etc.

KEY WORDS
product variety, inventory management, substitution effect, hospitals

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Introduction

Hospitals are known to use many products. The hospital staff responsible for managing products are constantly handling supply shortages and other logistical problems and challenges (Tucker & Edmondson, 2003).

To avoid supply shortages and improve cost control, many studies focused on optimising hospital inventory. Examples of such studies can be seen in the work by Varghese, Rossetti, Pohl, Apras, and Marek (2012) and Kritchanchai and Meesamut (2015). The

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latter identified potential cost savings of 14%. Besides this research on savings, it was found that proper hospital logistics handling helps to improve job satisfaction among the nursing staff (Landry & Beaulieu, 2013). One possible way to improve logistics performance is to reduce the number of products used in hospitals (Wan et al., 2012). This idea could be further elaborated considering the product variety, i.e., the range of products within a given group.

It is up to the medical staff to determine the demand for various devices as well as single-use medical products. However, not many (if any) among the medical staff have training in inventory handling. In general, their experience is that the available equipment is essential. Therefore, they tend to overestimate the need for the equipment based on an "in case of" strategy. For single-use products, such as bandages and compresses, one may discuss how many sizes and what kinds are necessary without having an impact on the quality of performed medical procedures.

The relevant question is whether there is a need for all sizes and types within a given product group. For example, for one type of bandages, a hospital may use five sizes. The largest and smallest of these may be used only once a year, resulting in waste due to the expiry date. Instead of having all sizes, one may substitute a smaller-size product with a large-size product, for example, a large bandage can be used on a smaller injury. This way, it is possible to substitute large and small bandages.

Current research (including the studies mentioned earlier) does not address these issues of product groups and product variety to the needed extent. This paper proposes a substitution method and investigates the effect on cost made by the substitution of an item with a similar item within a product group. The data used in this paper was collected from a rural hospital in Norway.

This paper is organised as follows. Section 1 provides a review of the literature on inventory management and product variety. Section 2 describes the data used in the research. Section 3 describes the substitution model developed for this study. Section 4 presents the results, which are further discussed in Section 5. Finally, the concluding comments and possible future research directions are presented.

1. Literature review

In general, hospitals are complex organisations that consist of various units, including those that provide various medical services to patients and those that are non-medical, such as administration, housekeeping etc. Each of these units performs distinctive functions, which require unique products. Thus, a hospital must maintain a considerable inventory, which results in high expenditures. Many studies indicate hospitals spending 25% to 30% of their budget on purchasing and handling the inventory (Ozcan, 2005).

Several inventory management methods have been developed for the reduction of costs and streamlining the inventory distribution process. Inventory optimisation is one of the most common methods to ensure the cost-effective management of inventory. The researchers Varghese et al. (2012) presented a case study for optimising inventory with the help of the r, Q inventory policy, based on which an order of Q quantities is placed for each r period. In this study, the authors found potential savings amounting to 14% from inventory present in the hospital's distribution centre. Similar savings were identified in the study conducted by Kritchanchai and Meesamut (2015). The authors developed an inventory planning model for "A" class products (high consumption) involving various inventory policies. In addition, the research pointed out the reduction of product shortage by 92.98%. One of the benefits of proper inventory management is the reduction of the inventory value present in the system. The authors Rachmania and Basri (2013) demonstrated a 50% reduction in the inventory value of oncology medications at a public hospital in Indonesia by using the s, Q policy, based on which an order of Q quantities is placed when the current stock level reaches s quantities.

The nature of hospital logistics is complex and multi-faceted. The propriety of managing the operations may benefit from exploring and adopting policies from logistics in other sectors. One such policy is the consideration of the product variety, which significantly impacts organisations in terms of profits and various supply-chain parameters. The research conducted by Wan et al. (2012) showed the importance of careful planning in terms of the level of product variety for organisations. The authors looked into a soft drink bottler with 108 distribution centres and found that the product variety had a direct negative effect on the fill rate of products, whereas the product sales were affected both directly and indirectly by the product variety. As product variety increases, the product sales initially increase as well, and after a certain point, the sales fall.

The product must be understood before making changes in the product variety at hospitals. One of the most straightforward approaches is the product hierarchy method proposed by (Malone, 1987). This approach was also used in the research by Fujita, Sakaguchi, and Akagi (1999) for product design and development, and in the article by Wang et al. (2011) for product manufacturing. These studies used a product hierarchy of three levels. The top level was comprised of the product family, which was followed by the product group or module, and finally, the product or module variants.

Erens and Verhulst (1997) mapped products based on the required function, technological realisation, and physical realisation. Fujita et al. (1999) used a similar concept; however, they defined the customer, function, and manufacturing viewpoints. The authors employed a binary integer programming model together with a specialised algorithm for the optimisation of the product variety. This research was performed in a company that designed television receiver circuits.

In several other studies, the issue of product variety was addressed with the help of the 0 – 1 integer programming approach. In the context of manufacturing, Wang et al. (2011) developed an optimisation problem to explore trade-offs between the product variety and the manufacturing complexity in the design of a mixed-model assembly system. The decision-making complexity of this research was related to the selection of best product variants to be manufactured on the assembly line considering various costs associated with their production. The main requirement for the optimisation of the product variance was to achieve the highest customer market share. Similar work was also conducted by Nishino, Takenaka, Koshiba, and Kodama (2014); however, this research dealt with the service industry.

Several researchers demonstrated the use of integer programming for product variety problems in the retail sector. In the work of McBride and Zufryden (1988), the product variety reduction was made based on customer preference. Borin, Farris, and Freeland (1994) came up with a decision-making framework based on the assortment and space allocation for products. Jayaraman, Srivastava, and Benton (1998) developed a non-linear optimisation model for the product variety, also considering inventory and product brands. The authors concluded that as the budget increased, the product variety could also be increased for achieving the desired profit for the retailer.

To sum up, the research in the areas of logistics for such contexts as manufacturing and retail has clearly demonstrated the benefits of carefully considered product variety. However, the area of hospital inventory management has not yet seen an in-depth study on the product variety. Therefore, the research presented in this paper aims to explore the reduction in the product variety combined with the inventory optimisation using a brute force analysis. The developed model and the results presented further contribute to the understanding of the effect made by the product variety and possible product substitutions on the inventory costs of hospitals.

2. Research data

The data was collected in a small rural hospital in Norway. The external order data for the duration of six years (2010–2015) was taken from the central database of the hospital. Each year, the hospital makes more than 6 000 external orders for a total of 2 331 products, of which 1 645 are sterile, and 686 are non-sterile. Currently, the hospital uses a two-level product hierarchy. The products are classified into ten product families, such as laboratory supplies, medical disposables, office supplies etc.

As defined in the literature, the product architecture, includes at least three levels, namely, the product family, the product group, and the product (Fujita et al., 1999). With the help of product mapping, an intermediate level was defined and named product groups, based on the function of the product. These product groups contained products which differed only by characteristics. In total, 1 481 product groups of sterile products and 532 product groups of non-sterile products were created. The values of product substitution factors used further in the model were defined manually based on product attributes such as size and quantity. Currently, the hospital does not optimise its inventory management. The model, which is developed and proposed further, addresses the issue of product variety and inventory optimisation.

3. Substitution modelling

Since the hospital uses a two-level hierarchy system for products, the authors of this article developed an intermediate level and called it "the product

group." This level will help the study into the product variety as it is intended for products which are used for the same purpose but differ based on their characteristics. For example, assume a hospital uses blister adhesive bandages of two different pack sizes 6 and 12, which belong in the product family of medical consumables. Therefore, in the product analysis, these two products can belong to a single group. Here, the quantity required for the substitution of one product with another varies; this can be termed many-to-one substitution. This many-to-one substitution makes it difficult to understand the effect of the product variety at hospitals. To understand this effect, the substitution model was developed and presented. This substitution model uses notations provided in Table 1.

A product group consists of N products, which creates 2^N possible ways to use products within this product group. This is similar to the 2k factorial design, which is commonly mentioned in the literature on the design of experiments (Sanchez, 2005). Table 2 represents the product selection for a product group of three products.

A simple condition in product usage is that at least one product in a product group must be used for each design point. The equation (1) represents this rule.

$$\sum_{i=1}^{N} U_i^p \geq 1 \qquad (1)$$

Therefore, product usage number 0 becomes invalid. Thus, this reduces the number of possibilities from eight to seven. Therefore, the number of possibilities for a product group with N products is $2^N - 1$.

Tab. 2. Product usage for a product group containing three products

Product usage number	U_1	U_2	U_3
0	0	0	0
1	1	0	0
2	0	1	0
3	1	1	0
4	0	0	1
5	1	0	1
6	0	1	1
7	1	1	1

3.1. Estimated product substitution

For most of the product usage numbers, there are one or more unused products. In these instances, their demand must be substituted for by another product. Therefore, irrespective of whether a product can substitute for another product, demand substitution is done. For simplification purposes, a simple rule applies that only one product can be used to substitute for another product for a design point and, thus, invalidates the partial substitutions. Therefore, the number of substitutions is equal to the number

Tab. 1. Notations used in the substitution model

Notation	Description
N	Total number of products within the product group
i, j	Product number within the product group; $i, j \in (1,\ldots,N)$
p	Notation used for product usage number
M	Notation used for the design point
U_i^p	$\begin{cases}1, & \text{if product } i \text{ within the product group is used in the product usage number}\\ 0, & \text{Otherwise}\end{cases}$
U_i^M	$\begin{cases}1, & \text{if product } i \text{ within the product group is used in the design point } M\\ 0, & \text{Otherwise}\end{cases}$
U_j^M	$\begin{cases}1, & \text{if product j within the product group is used in the design point } M\\ 0, & \text{Otherwise}\end{cases}$
W_{ji}^M	$\begin{cases}1, & \text{if product j within the product group is used in the design point } M \text{ where } U_j^M\\ 0, & \text{Otherwise}\end{cases}$
S_{ij}^M	$\begin{cases}x, & \text{if x units of product i can substitute 1 unit of product } j \text{ within the product group at the design point } M\\ 0, & \text{Otherwise}\end{cases}$ Where x is a real number
R_{ij}^M	$\begin{cases}1, & \text{if } S_{ij}^M \neq 0\\ 0, & \text{if } S_{ij}^M = 0\end{cases}$
ID_i	Initial demand of product i within the product group
CD_i^M	Modified demand of product i within the product group at the design point M with the replacement factor
D_i^M	Modified demand of product i within the product group at the design point M with the conversion factor
LC_i^M	Logistics cost of product i within the product group at the design point M
TC_i^M	Total cost of product i within the product group at the design point M
LC^M	Summation of logistics cost of products in the product group at the design point M
TC^M	Summation of the total cost of products in the product group at the design point M

$$\sum_{i=1}^{N} W_{ji}^{M} = 1, \forall\, j\colon U_j^M = 0 \tag{2}$$

$$\sum_{i=1}^{N}\sum_{j=1}^{N} W_{ji}^{M} = N - \sum_{i=1}^{N} U_i^M \tag{3}$$

$$\text{Number of design points} = \left(\sum_{i=1}^{N} U_i^M\right)^{N-\sum_{i=1}^{N} U_i^M} \tag{4}$$

Tab. 3. Number of possible product usage and design points based on size of product groups

Size of Product Group	No. of possible product usage	No. of Design Points
1	1	1
2	3	3
3	7	10
5	31	196
8	255	41393
10	1023	2237921
15	32767	$1.39 * 10^{11}$

Tab. 4. Design points for a product group of three products

Design Points	U_1	U_2	U_3	W_{1j}	W_{2j}	W_{3j}
1, 1	1	0	0	0	0	0
				1	0	0
				1	0	0
2, 1	0	1	0	0	1	0
				0	0	0
				0	1	0
3, 1	1	1	0	0	0	0
				0	0	0
				1	0	0
3, 2	1	1	0	0	0	0
				0	0	0
				0	1	0
4, 1	0	0	1	0	0	1
				0	0	1
				0	0	0
5, 1	1	0	1	0	0	0
				1	0	0
				0	0	0
5, 2	1	0	1	0	0	0
				0	0	1
				0	0	0
6, 1	0	1	1	0	1	0
				0	0	0
				0	0	0
6, 2	0	1	1	0	0	1
				0	0	0
				0	0	0
7, 1	1	1	1	0	0	0
				0	0	0
				0	0	0

of products unused in a design point. This is represented in equations (2) and (3).

For each product usage number, there are various possibilities of product substitutions, for example, in a product group containing three products, when two of the products are selected for usage, and one is unused. In this example, either of the other two products, i.e., two different combinations, occur for this possibility of substituting the demand of the unused product. Based on this, the number of possibilities that occur for each product usage number is represented in equation (4). Table 3 presents the number of possibilities of product usage and several design points based on the size of the product group.

Table 4 presents the usage of products with the notation U_i and product substitution with the notation W_{ij} for a product group of three products.

3.2. Product replacement constraint

The next step is to make sure that the design points are valid. For this, a new variable CD^i_M (Demand check of product *i* in design point *M*) is introduced. The calculation for this variable is presented in equation (5). If a product i substitutes for another product j in a design point, then the demand of product *j* is added to the demand of product *i*. For a design point, the summation of demands of all products is equated to the summation of check demand. If this is true, then the design point is valid. This is to make sure that the demand for unused

$$CD_i^M = U_i^M\left[ID_i + \sum_{j=1}^{N}\left(1 - U_j^M\right) W_{ji}^M R_{ij}^M ID_j\right] \tag{5}$$

products is satisfied with other products. It is represented by equation (6).

$$\sum_{i=1}^{N} CD_i^M = \sum_{i=1}^{N} ID_i \tag{6}$$

3.3. Modified demand

For all the valid design points, the new demand for the products in the product group is calculated by equation (7). The difference between equations (6) and (7) is the usage of the replacement factor and the substitution factor, respectively.

$$D_i^M = U_i^M\left[ID_i + \sum_{j=1}^{N}\left(1 - U_j^M\right) W_{ji}^M S_{ij}^M ID_j\right] \tag{7}$$

3.4. Cost calculation

The ordering quantity for the modified demand is calculated based on the economic order quantity and cost functions under the stochastic condition. The objective is to find the values of cost for a product group for each design point, as shown in equations (8) and (9).

$$LC^M = \sum_{i=1}^{N} LC_i^M \quad (8)$$

$$TC^M = \sum_{i=1}^{N} TC_i^M \quad (9)$$

4. Results

The model was programmed using Microsoft Excel and the visual basic application (VBA) language. Assumptions made for the study are listed below.

- Carrying charge for the products was 20%.
- Expected length of lead-time of 3 days and the standard deviation of 0 days was considered for products for which the supplier details were missing.

4.1. Product substitution effect

One of the focus points for the research is to understand the product substitution effect. Here, the results are presented for both types of substitution, namely one-to-one substitution and many-to-one substitution. For this, the authors of this article used a non-sterile product group containing products that differ by colour for one-to-one substitution, and a sterile product group containing products that differ by size for many-to-one substitution.

4.2. One-to-one substitution

The notation NSP_i is used to represent the non-sterile product group, where *i* represents the product number within the product group. Since products within the product group differ based on colour, the substitution factor between these products is one. The initial details of the products in this product group are presented in Table 5.

Earlier, the authors of the article presented all the design points for a product group of three products in Table 4. The hospital currently uses all the products within the product group, which is formed in the design point (7, 1). In this design point, the net logistics cost accounts to NOK 205.66 and the total cost accounts to NOK 330.49, which is presented in Table 6. Both these costs will act as a baseline for cost comparisons.

Tab. 5. Initial details of products within the non-sterile product group

	Demand	Avg. Unit Cost
NSP_1	260	NOK* 0.172
NSP_2	461	NOK 0.127
NSP_3	162	NOK 0.133

* Conversion rate as on 21.12.2019: 1 NOK = 0.11 USD
Source: https://www.xe.com/

Tab. 6. Cost when all the products in the product group are used

Design Point: (7, 1)	NSP_1	NSP_2	NSP_3	Total
Demand (Units)	260	461	162	883
Logistics Cost (NOK)	72.43	82.94	50.28	205.66
Total Cost (NOK)	117.13	141.52	71.84	330.49

In the remaining nine design points, at least one product is unused, and another product substitutes for its demand. For the design points (1, 1), (2, 1) and (4, 1), only one product is used, and in the remaining six design points, two products are used. The summary of the values of the added demand together with the related costs and the potential savings are provided in Table 7. The usage of only product NSP_2 occurring in the design point (2, 1) had a potential saving of 31% of the total cost. As the results suggest, the reduction of any product in this product group would result in minimum savings of 4%. Therefore, at least one product should be given up in this product group to save cost.

4.3. Many-to-one substitution

The notation SP_i is used to represent the sterile product group, where i represents the product number within the product group. The selected product group contains two products within the product group. Table 8 presents the demand and unit cost for the products in the product group.

The products in this product group differ based on size. Consequently, the product substitution factor may or may not be one. Table 9 shows the product substitution factor for both the products in the product group.

At present, the hospital uses both products in the product group, which is formed in the design point (3, 1). The costs in this instance will be the reference

Tab. 1. Cost when products are reduced from product group

Design Point		**(1, 1)**			**(2, 1)**			**(3, 1)**			**(3, 2)**			**(4, 1)**		
Description		NSP_1 is used. NSP_2 & NSP_3 are substituted by NSP_1			NSP_2 is used. NSP_1 & NSP_3 are substituted by NSP_2			NSP_1 & NSP_2 are used. NSP_3 is substituted by NSP_1			NSP_1 & NSP_2 are used. NSP_3 is substituted by NSP_2			NSP_3 is used. NSP_1 & NSP_2 are substituted by NSP_3		
Product		NSP_1	NSP_2	NSP_3	NSP_1	NSP_2	NSP_3	NSP_1	NSP_2	NSP_3	NSP_1	NSP_2	NSP_3	NSP_1	NSP_2	NSP_3
Initial Demand	(Units)	260	0	0	0	461	0	260	461	0	260	461	0	0	0	162
Added Demand	(Units)	523	0	0	0	422	0	162	0	0	0	162	0	0	0	721
Modified Demand	(Units)	883	0	0	0	883	0	422	461	0	260	623	0	0	0	883
Logistics Cost of Products	(NOK)	133.39	0.00	0.00	0.00	114.73	0.00	92.25	82.94	0.00	72.43	96.4	0.00	0.00	0.00	117.31
Total Cost of Products	(NOK)	285.19	0.00	0.00	0.00	226.94	0.00	164.8	141.52	0.00	117.13	175.56	0.00	0.00	0.00	234.82
Logistics Cost for Product Group	(NOK)	133.39			114.73			175.19			168.83			117.31		
Total Cost for Product Group	(NOK)	285.19			226.94			306.32			292.69			234.82		
% saving Logistics Cost		35.14			44.21			14.81			17.91			42.96		
% saving Total Cost		13.71			31.33			7.31			11.44			28.95		

Design Point		**(5, 1)**			**(5, 2)**			**(6, 1)**			**(6, 2)**		
Description		NSP_1 & NSP_3 are used. NSP_2 is substituted by NSP_1			NSP_1 & NSP_3 are used. NSP_2 is substituted by NSP_3			NSP_2 & NSP_3 are used. NSP_1 is substituted by NSP_2			NSP_2 & NSP_3 are used. NSP_1 is substituted by NSP_3		
Product		NSP_1	NSP_2	NSP_3	NSP_1	NSP_2	NSP_3	NSP_1	NSP_2	NSP_3	NSP_1	NSP_2	NSP_3
Initial Demand	(Units)	260	0	162	260	0	162	0	461	162	0	461	162
Added Demand	(Units)	461	0	0	0	0	461	0	260	0	0	0	260
Modified Demand	(Units)	721	0	162	260	0	623	0	721	162	0	461	422
Logistics Cost of Products	(NOK)	120.54	0.00	50.28	72.43	0.00	98.55	0.00	103.69	50.28	0.00	82.94	81.12

Total Cost of Products	(NOK)	244.49	0.00	71.84	117.13	0.00	181.46	0.00	195.31	71.84	0.00	141.52	137.28
Logistics Cost for Product Group	(NOK)	170.82			170.98			153.97			164.06		
Total Cost for Product Group	(NOK)	316.33			298.59			267.15			278.8		
% saving Logistics Cost		16.94			16.86			25.13			20.23		
% saving Total Cost		4.29			9.65			19.17			15.64		

Tab. 8. Initial data of the product group

	Demand	Avg. Unit Cost
SP_1	50	NOK 54.95
SP_2	37	NOK 73.53

Tab. 9. Substitution factor of the product group

	SP_1	SP_2
SP_1	1	2
SP_2	1	1

Tab. 10. Cost when both products are used

Design Point: (3, 1)	SP_1	SP_2	Total
Demand (Units)	50	37	87
Logistics Cost (NOK)	577.20	576.11	1 153.31
Total Cost (NOK)	3 324.46	3 296.70	6 621.15

Tab. 11. Cost when only one product is used

Design Point		(1, 1)		(2, 1)	
Description		SP_1 is used. SP_2 is substituted by SP_1		SP_2 is used. SP_1 is substituted by SP_2	
Product		SP_1	SP_2	SP_1	SP_2
Initial Demand	(Units)	50	0	0	37
Added Demand	(Units)	74	0	0	50
Modified Demand	(Units)	124	0	0	87
Logistics Cost of Products	(NOK)	903.11	0.00	0.00	876.99
Total Cost of Products	(NOK)	7 716.30	0.00	0.00	7 274.05
Logistics Cost for Product Group	(NOK)	903.11		876.99	
Total Cost for Product Group	(NOK)	7 716.30		7 274.05	
% saving Logistics Cost		21.69		23.96	
% saving Total Cost		- 16.54		- 9.86	

for making the cost-saving calculation. The net logistics cost is NOK 1 153.31, and the total cost is NOK 6 621.15, which is represented in Table 10.

Since this product group contains only two products, a reduction can occur by one product generated in two design points (1, 1) and (2, 1). This reduction of the product in both design points results, in logistics cost savings amounting to more than 20% and an increase in the total cost due to the product cost. These results are presented in Table 11. Therefore, for this product group, both products should be used. This product group was chosen to demonstrate the effect of product substitution factor.

4.4. Overall results

For each product group, the design point creating the lowest total cost is selected for summarisation of the results. The summary is presented in Table 12. For this hospital, the model generates a reduction of 262 items with a potential cost saving of 22.3% which is an increase of 3.80% when the inventory is optimised. The split up of the results shows that the sterile products provide cost saving of 22.97% whereas the non-sterile products generate only 13.43% in cost savings.

5. Discussion

In this hospital, the number of sterile products used is more than twice the number of non-sterile products used. A baseline was demonstrated to provide the potential of the reduction in the product variety for this hospital. Approximately 7% of sterile products and 21% of non-sterile products could be reduced. Therefore, more than 11% of product varieties may be reduced. Since two different types of product substitution were explored, they should be discussed individually.

For one-to-one product substitution, a non-sterile product group containing three products was

Tab. 12. Overall results

		Sterile	Non-Sterile	Total
Current Process	Number of Products	1645	686	2331
	Logistics Cost (NOK)	2 027 437	1 240 102	3 267 540
	Total Cost (NOK)	9 890 439	6 334 964	16 225 404
All products used with optimised Inventory	Number of Products	1645	686	2331
	% reduction in number of Products	0.00	0.00	0.00
	Logistics Cost (NOK)	663 507	245 603	909 110
	% reduction in logistics Cost	67.27	80.19	72.18
	Total Cost (NOK)	7 651 830	5 572 990	13 224 820
	% reduction in total Cost	22.63	12.03	18.49
Substitution Model	Number of Products	1524	545	2069
	% reduction in number of Products	7.36	20.55	11.24
	Logistics Cost (NOK)	636 228	215 468	851 696
	% reduction in logistics Cost	68.62	82.62	73.93
	Total Cost (NOK)	7 123 596	5 483 927	12 607 523
	% reduction in total Cost	27.97	13.43	22.30

inspected. When all the products were used, the logistics cost was NOK 205.66, and the total cost was NOK 330.49. With the reduction of just one product, there was a drop in both the logistics costs and the total costs. The drop in the logistics cost was 14% – 25%, and the drop in the total cost was 4% – 19%. This difference occurred due to the presence of product cost. The substitution of the product NSP_1 by NSP_2 and the usage of NSP_3 showed better results. When there was the usage of only one product, the logistics cost decreased somewhat between 35% – 44% and the total cost decreased by 13% – 31%. The usage of only NSP_2 alone gave better results. Due to the variation in the cost per product of NSP_2 and NSP_3 in the third decimal place, NSP_2 gave better results. In other words, the selection of the product with the lowest cost per product value yielded better results. This simplification was possible because the substitution factor between the products was one.

For many-to-one product substitution, a sterile product group containing two products was examined. When both products were used, the logistics cost was NOK 1 153.31, and the total cost was NOK 6 621.15. When only one product in the product group was used, the logistics cost dropped between 21% – 24%, whereas the total cost increased between 9% – 17%. The drop in the logistics cost was possible because of pooling the demands of products. The increase in the total cost occurred due to the combination of both cost per product and the substitution factor. When SP_1 was used, the cost of product SP_2 was NOK 73.53, and the product of the substitution factor when SP_2 was substituted with SP_1, and the cost per product of SP_1 was NOK 109.90. The cost per product of SP_2 was higher than that of SP_1. Therefore, in both these instances, it resulted in a higher total cost when compared to the usage of both products. Since this product group contained only two products, the comparisons were easier. It would become more complex with the increase in the size of a product group.

The overall result shows that 262 (11%) product varieties could be reduced, resulting in a cost-saving of more than NOK 3.6 million (22.3%). According to research by Wan et al. (2012), the sales of products increase with the increase in the product variety until it reaches an optimum point and then decrease. Similarly, these results indicate that the reduction of all varieties in the product group does not yield cost reduction. The costs saved at this hospital are rather small, but on the scale of all 85 hospitals in Norway, it would result in approx. NOK 307.5 million. Thus, the study into the product variety of inventory at hospitals can bring considerable cost savings.

Conclusions

This paper investigated the influence of the product variety on hospital inventory based on the product substitution factor and the corresponding inventory cost. After the discussion of the literature, the developed model for the study was presented. This model is universal in nature and can be used in other fields, such as retail, marketing etc. The developed model contributes to the pool of literature focusing on the analysis decision-making with respect to product variety based on product attributes as well as inventory management. The influence of the substitution factor on the product variety decision was presented together with the corresponding inventory cost. The results showed a combined influence of the product substitution factor and the product unit cost.

Various additional aspects may be considered to contribute to the knowledge of the effects of the product variety on the inventory of hospitals. One of the limitations of the research presented in this article is that it does not address issues such as time taken by healthcare personnel to adapt to this change or flexibility of the hospital and other factors. Among other limitations, this research does not consider the replenishment coordination and floor space limitations. Future research may focus on having these aspects included in modelling to produce better real-time results. This research also does not account for healthcare personnel's preference for products. This aspect may prove to be a crucial factor influencing the implementation of the produced modelling results on the product variety. The incorporation of the personnel's preference into the decision-making can ensure that preferred products do not get eliminated by the decision-making framework. These are some ideas for possible future research.

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AutoCAD: examination of factors influencing user adoption

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ABSTRACT
The primary purpose of the research is to examine and validate determinants of user intention to use AutoCAD software, utilising the constructs from prior studies in a more integrated model. The paper proposes a revised Technology Acceptance Model (TAM) for measuring the adoption of AutoCAD. In the study, a latent construct PPA (perceived physical accessibility) was added to the proposed research model as a new determinant of AutoCAD adoption. An online survey of AutoCAD users was conducted to collect data. This data was empirically used to test the proposed research model. The Structural Equation Modelling (SEM) technique was used to evaluate the causal model, and the confirmatory factor analysis was performed to examine the reliability and validity of the measurement model. The study results show that user behavioural intention to use AutoCAD is significantly affected by three determinants: perceived usefulness, perceived ease of use and perceived physical accessibility of the software. This finding contributes to an expanded understanding of the factors that promote acceptance of AutoCAD software. Moreover, the main contribution of this study is to verify the impact of the added PPA variable on the behavioural intention to use and the actual use of AutoCAD, and also to create measurement scales for this new latent variable in TAM.

KEY WORDS
Technology Acceptance Model, TAM, AutoCAD software, the determinants of IT adoption, IT accessibility

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Introduction

Considering the rapid growth of the use of information technologies (IT) in business and in such areas as engineering, the subject of acceptance and evaluation of AutoCAD software used by engineers in the process of designing deserves special attention. An understanding of what determines the adoption of software may provide information that will contribute to the promotion of its success.

The problems related to the promotion and analysis of IT applications are among the leading fields of business informatics studies. The theories proposed in

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this area concentrate on explaining the success and failure drivers related to the implementation of different types of software in organisations, as well as on looking for determinants that facilitate or obstruct the IT adoption by organisations and individual users.

In research, IT adoption is most often explained using the Technology Acceptance Model (TAM). It evolved from the Theory of Reasoned Action (TRA), which is used in many different fields of study to predict and explain human behaviours that are motivated by rational actions and the intention to control behaviour.

Originally proposed by Davis, TAM has been subject to several modifications tested with the help of different computer systems, such as the WriteOne text editor (Davis et al., 1989), YouTube as a learning resource (Chintalapati et al., 2016), open-source software (Przechlewski, 2012), and the use of mobile apps in higher education (Han Wai et al., 2018). Although TAM has been applied to a great number of areas for modelling the usefulness and the use and adoption of different IT, no studies on AutoCAD could be found (more: Section 3). This gap in the literature for the adoption of AutoCAD as a technology for supporting the engineering work is addressed in the current research.

The purpose of this study is to examine and validate determinants of user intention to use AutoCAD, utilising the constructs from prior studies in a more integrated model. In this research, apart from the two main TAM determinant factors — PU (perceived usefulness) and PEOU (perceived ease of use) — the PPA (perceived physical accessibility) was added to the proposed research model as another determinant of AutoCAD adoption.

The rest of the paper is organised as follows: Section 1 provides an overview of the research background; Section 2 reviews the related works; Section 3 describes the research model and hypotheses; Section 4 presents the data collection procedures and the research method used in this study. Then, results are presented and subsequently discussed. The last section summarises and concludes this paper.

1. Research background

The author's professional and teaching experience shows that although the market offers many computer-aided design systems (e.g., SolidWorks, GstarCAD, I-DEAS, Inventor or Fusion), AutoCAD is the most popular. Most university or college engineering study programmes are based on this application. Is this the right choice? What is the adoption of this software among users? How do they perceive its potential as regards the ease of use, usefulness or accessibility? This research was conducted to help answer these questions as well as fill the knowledge gap regarding a model that explains the adoption of AutoCAD among users. Based on the literature review provided in Section 2, the author decided to choose the Technology Acceptance Model as the basis of this study.

1.1. TAM model

The Technology Acceptance Model is often used in acceptance analyses of different types of IT solutions. The value of any technology can be best appraised by its users, who only choose to use it if the benefits outweigh the cost. TAM was proposed by Davis in 1986 to explain what motivates people to accept or reject a piece of technology. TAM is derived from the Theory of Reasoned Action (TRA) (Fishbein & Ajzen, 1975; Ajzen & Fishbein, 1980), which is a psychological model, according to which any action is preceded by intention (behavioural intention, BI) that is determined by subjective norms and attitudes towards behaviours. TAM is based on two main predictive factors: whether users perceive technology as useful (perceived usefulness — PU) and easy to use (perceived ease of use — PEOU). Davis defined the perceived usefulness as "the degree to which a person believes that using a particular system would enhance his or her job performance," while the perceived ease of use as "the degree to which a person believes that using a particular system would be free from effort" (Davis, 1989, p. 320). These two variables included in the TAM model predict a user approach to technology and the influence on their intention (BI) to accept it and use it. It should be stressed that TAM was subject to many modifications over the years (Davis et al., 1989, p. 985; Davis, 1993, p. 481), to be presented in its final version in 1996 (Venkatesh & Davis, 1996, p. 453). This study used this version of the model.

Lim (2018) suggested that TAM should be regarded as "a model that increases opportunities to understand the peculiarities of user interactions with technology in contemporary technology-mediated environments, not limiting them." With this suggestion in mind, the purpose of this study was to analyse and understand user relationships with AutoCAD and to extend TAM so as to work up theory and practice.

1.2. AutoCAD

AutoCAD was developed by Autodesk as a tool for two-dimensional (2D) and three-dimensional (3D)

computer-aided designing (CAD). The software is commonly used in many industries by design engineers, mechanics, architects and other designers. It is a closed-source, proprietary, legally reserved program. In other words, it is not only subject to use, copy and modification restrictions, but also licensed to its users for a fee. There are different purchase and access procedures for corporate users and private individuals. Licences are time-limited and offered as monthly, quarterly, annual, two-year and three-year plans. The price to be paid is relatively high and may differ, depending on a region and access type (stationary, mobile, cloud-based, single user or multiple users). Furthermore, there is a trial version with a built-in 30-day time limit. Due to the facts mentioned above and the high cost of the licence, AutoCAD has many strong competitors, e.g. GstarCAD with interfaces and features very similar to AutoCAD. The price of a lifetime licence for GstarCAD is comparable with the monthly cost of the AutoCAD subscription.

The costly AutoCAD licence has become the reason for including a new variable in the TAM model here, namely PPA — the perceived physical accessibility (more: Section 3).

2. Studies on TAM models

For an overview of existing studies, papers published in Scopus indexed journals were selected using TAM-related key words in abstracts as a selection criterion. The search query yielded a set of 1419 papers published in the years 1997–2018. First, most frequently cited papers were selected for analysis. Then, attention was given to earlier studies to identify constructs to be used in the proposed model.

The authors with the highest citation index of 1634 (Moon & Kim, 2001) extended TAM for the WWW context with playfulness as a new factor that reflects the user intrinsic belief in the WWW acceptance. Another interesting and highly cited paper was authored by Venkatesh and Bala (2008) analysing how to enhance employee adoption and use of information technologies at a workplace. Their findings have important implications for managerial decisions as regards IT implementation in organisations. Wu and Wang (2005) analysed what determines mobile commerce user acceptance, adding such additional variables to TAM as risk and cost. The researchers identified the positive influence of perceived risk on behavioural intention to use (BI). TAM was tested in many empirical studies. Table 1 presents the list of studies with a synthetic summary of constructs used in TAM models and the summary of findings. The table also includes three projects from the 1980s due to their relevance to the present study.

Literature analyses show that TAM was tested in many areas. It is highly predictive of the user willingness to use and their acceptance of IT. The existing studies were based on different versions and extensions of TAM. Some of them concentrated on integrating new constructs with proposed models. The overview did not identify any analyses of AutoCAD acceptance. Furthermore, the literature analysis shows a deficit of an essential construct that might address different types of barriers preventing users from using IT. For commercial software, it would be particularly important to include such variable, since the cost of a licence represents the initial barrier to software accessibility. Although the Accessibility construct appears in the analysis of the literature on the use of TAM models (Rice & Shook, 1988; Thong et al., 2002; Park, 2009), it does not encompass all aspects of what should be included in this variable for AutoCAD or any other commercial software. For this reason, the present study aims to extend the proposed model that analyses the adoption of AutoCAD by adding a new variable — PPA (the perceived physical accessibility). Considering that there has been no construct like this in the existing studies so far, the objective of the work was expanded so as to develop adequate measurement scales.

Perceived accessibility was found to be one of the important determinants of the frequency of using IT (Culnan, 1985). Thong et al. (2002) defined accessibility as the ease with which people can locate specific IT. According to Culnan (1985), accessibility is a multidimensional concept encompassing physical access to IT. Accessibility perception is moderated by different factors, such as the cost of software, physical access restrictions due to the place where users are able to use the installed software (e.g. at work only), or limited time of application accessibility (more: Section 3). The PPA variable added to the model will include such accessibility barriers to this commercial application.

3. Conceptual model and research hypotheses

The main purpose of the TAM is to explain the determining factors in end-user adoption of computer technologies. This research adopted a simplified TAM from Venkatesh and Davis (1996, p. 453) and the new variable PPA (the perceived physical accessibility) was included. Variables in the model:

Tab. 1. Previous TAM research

Authors	Constructs	Applications	Findings
Rice and Shook (1988)	Accessibility, USE, Value, Job Type, Appropriate, Outcomes	Electronic Messaging System (EMS)	Accessibility→USE, Job Type→USE, Value→USE, USE→ Outcomes
Davis (1989)	PU, PEOU, USE*	PROFS - electronic mail, the XEDIT file editor, and IBM PC-systems: Chart-Master, Pendraw	PEOU→USE, PU→USE
Davis et al. (1989)	PU, PEOU, ATT, BI, USE	WriteOne	PEOU→PU, PU→ATT, PEOU→ATT, ATT→BI, BI→USE, PU→BI
Teo et al. (1999)	PU, PEOU, USE, PE	Internet	PEOU→PU, PU→USE, PEOU→USE, PE→USE, PEOU→PE
Thong et al. (2002)	PU, PEOU, BI, System Accessibility (SA), Terminology, Screen Design, Navigation, Relevance, System Visibility, Computer Self-Efficacy (CsE), Computer Experience (CEx), Domain Knowledge (DK),	digital library	Terminology→PEOU, Screen Design→PEOU, Navigation→PEOU, Relevance→PU, System Visibility→PU, CsE→PEOU, CEx→PEOU, DK→PEOU, PEOU→PU, PEOU→BI, PU→BI
Park (2009)	PU, PEOU, ATT, BI, SN System Accessibility (SA)	e-learning	ATT→BI, SE→BI, SN→BI, PU →ATT, PEOU→ATT, SN→ATT, PEOU→ PU, SE, SN→PU, SE→PEOU, SA→PEOU
Liébana-Cabanillas et al. (2015)	PC, PU, ATT, BI, PEOU, Personal Innovativeness (PI),	QR mobile payment system	PC→PU, ATT→BI, PU→ATT, PEOU→ PU, PI→ PEOU, PI→BI, SN→BI
Chintalapati et al. (2016)	PU, PEOU, ATT, BI	YouTube	PEOU→PU, PU→ATT, ATT→BI, PEOU→ATT
Bazelais et al. (2017)	PU, PEOU, USE, ATT, BI	online learning technologies for college students	PEOU→PU, PU→ATT, ATT→BI, PEOU→ATT
Park et al. (2017)	Technology Acceptance (TA), PE, ATT, BI, PU, PEOU, Perceived connectedness (PCON), PC, Perceived control (PCO), Perceived cost (PCOST)	Internet of Things (IoT)	ATT→ BI, PU→ BI, PU→ ATT, PEOU→ATT, PEOU→ PU, PCOST→BI PCON→PU, PC→PEOU, PCON→PEOU, PC→PU, PCO→PEOU
Ahmad et al. (2017)	PU, PEOU, Trust (TR), Cost, Social Influence (SI), Variety of services (VOS), User intention to adopt eGovernment (eG), control variables: Gender, Age and Household income	m-government service	TR→eG, SI→eG, Gender→eG, Age→eG, Household income→eG
Ul Hassan et al. (2018)	COST, BI, PU, PEOU, Securuty&Privacy (S&P), ATT, SN, Perceived Behavioural Control (PBC), Self-Efficacy (SE)	Internet banking	PU→ATT, PEOU →ATT, ATT→BI, SE→PBC, PBC→BI, SN →BI, S&P →ATT, TS→PBC, COST→ BI
Changchit and Chuchuen (2018)	PU, PEOU, Perceived Security (PS), Perceived Speed of Access (PSA), Perceived Cost of Usage (PCU)	Cloud Computing	PU→BI, PEOU→BI, PS→BI, PCU→BI
Sangi et al. (2018)	PU, Communication (C), Cost-effectiveness (CE), Smartphones usage (SU), Facebook Usage (FbU)	Facebook	PU→FbU, C→FbU, SU→FbU
Groß (2018)	PU, PEOU, USE, PE, ATT, Trust (TR), Social influence (SI), Satisfaction (SAT)	mobile shopping	PU→ATT, PE→ATT, PEOU→ATT, SI→BI, PEOU→PU, PEOU→PE, ATT→BI, TR→BI, BI→USE, SAT→USE

*Legend: PEOU — perceived ease of use; PU — perceived usefulness; ATT — attitude; BI — behavioural intention; PE — perceived enjoyment; SN — subjective norms; PC — perceived compatibility.

- the perceived usefulness (PU), i.e. answers to the following questions: What can the new technology be used for? Will it make my tasks easier to perform?
- the perceived ease of use (PEOU), i.e. the following considerations: Will using the new technology require much work and effort from me?
- the behavioural intention to use (BI) is a measure of the likelihood that a person will employ the application;
- the technology use (USE) — the actual use of the technology;
- the perceived physical accessibility (PPA) is expected to show how the user perceives the accessibility of the technology. By adding this variable, barriers to and difficulties with accessing the software are expected to be included in the model.

AutoCAD is a commercial product and users have to pay for the licence. This implies four perspectives that have been considered by adding the PPA to the model:

- place (including distance) where users may use AutoCAD (PPA1),
- subjective perception of a user of access barriers/limitations (PPA2);
- cost of obtaining the application (PPA3);
- time (unlimited or limited by, e.g., work/school hours, or using the trial version), when the user may use AutoCAD (PPA4).

The revised TAM is shown in Fig. 1.

The following hypotheses are proposed in the model presented here:

- H1. (PEOU → PU) Perceived ease of use has an effect on perceived usefulness.
- H2. (PU → BI) Perceived usefulness has an impact on behavioural intention to use.
- H3. (PEOU → BI) Perceived ease of use has an effect on behavioural intention to use.

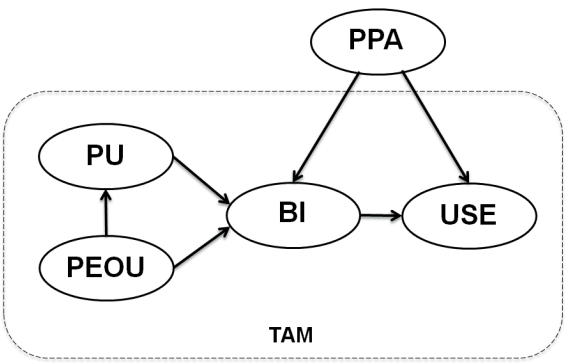

Fig. 1. Proposed research model

- H4. (PPA → BI) Perceived physical accessibility has an impact on behavioural intention to use.
- H5. (BI → USE) Behavioural intention to use has an effect on the actual use.
- H6. (PPA → USE) Perceived physical accessibility exerts an impact on the actual use.

4. Study design, data collection procedures and the used research method

The research procedure began with a literature review intended to identify measurement scales for the variables in the model. To ensure that a comprehensive list of scales was included, works of other authors were reviewed. As mentioned before, the latent variable PPA was added to the TAM — a variable, for which the existing literature had not provided any defined and tested measurement scales. To measure PPA, four questions were asked in the questionnaire with the answer scales defined by the author. Table 2 presents a summary of all variables of the model, with the measures used in the analysis.

To collect data needed to perform the analyses and to test the hypotheses, a questionnaire survey was conducted in 2019 in Poland. The online survey was created using the Google Forms service. To begin with, a pilot survey was conducted with respondents who declared extensive experience in using AutoCAD. Its aim was to check how the questionnaire worked in terms of clarity of the questions and whether the instrument captured the elements sought without omitting any important aspects. The questionnaire consisted of five headline questions describing the respondent profile (gender, age, education, job, experience) and five latent variables (each of them in a separate section of the questionnaire).

4.1. Respondents

The survey respondents were recruited from among individuals who had been using AutoCAD for a few months at least. This criterion allowed BSc students (81.4% of the respondents), MSc students (5.4%), as well as professionally active design engineers who were using AutoCAD in their everyday work.

Students as subjects are appropriate for this type of study as they are certainly part of future target groups for AutoCAD software. As a generation surrounded by and intensively using digital technologies in their life, students can provide a new perspective on the

Tab. 2. Construct measurement and scale items

Variable	Constructs	Source/Reference
PEOU	**Perceived ease of use**	
PEOU1	Learning to use AutoCAD is easy for me	Igbaria et al. (1997); Karahanna et al. (2006); Venkatesh et al. (2003)
PEOU2	I can easily do what I want and need in AutoCAD	Davis (1989)
PEOU3	My interaction with AutoCAD is clear and understandable	Karahanna et al. (2006); Venkatesh and Davis (2000)
PEOU4	I can easily use AutoCAD efficiently	F. D. Davis (1989); Karahanna et al. (2006)
PEOU5	AutoCAD is an intuitive program	Author
PU	**Perceived usefulness**	
PU1	Using AutoCAD enables me to accomplish tasks more quickly	Davis (1989); Venkatesh et al. (2003)
PU2	Using AutoCAD increases my productivity	Davis (1989); Venkatesh et al. (2003)
PU3	Using AutoCAD enhances my work effectiveness	Davis (1989); Igbaria et al. (1997); Venkatesh and Davis (2000)
PU4	Using AutoCAD makes it easier to do my job	Karahanna et al. (2006)
PU5	I find AutoCAD useful in my job	Davis, 1989; Igbaria et al. (1997) Venkatesh and Davis (2000)
BI	**Behavioural intention**	
BI1	I intend to use AutoCAD in the next six months	Venkatesh et al. (2003)
BI2	Given that I have access to AutoCAD, I predict that I would use it	Venkatesh and Davis (2000)
BI3	I will use AutoCAD on a regular basis in the future	Lai and Li (2005)
BI4	I will strongly recommend others to use AutoCAD	Lai and Li (2005)
BI5	I intend to increase my use of AutoCAD in the future	Agarwal and Prasad (1998); Lai and Li (2005)
PPA	**Perceived physical accessibility**	
PPA1	(distance/place) I can use AutoCAD installed[1]	Author
PPA2	(difficulty of access) I can access AutoCAD[2]	Author
PPA3	(cost) Obtaining AutoCAD was[3]	Author
PPA4	(time) I can use AutoCAD[4]	Author
USE	**Actual use**	
USE1	I use AutoCAD less than once a week	Davis et al. (1989)
USE2	I always use AutoCAD whenever I have a project to do	Author
USE3	I have used AutoCAD in the last six months	Groß (2018)
USE4	I use AutoCAD more than once a day	Davis et al. (1989)
USE5	I use AutoCAD regularly four to six times per week	Davis et al. (1989)

* Variables PEOU1–5, PU1–5, BI1–5 and USE1–5 are measured with the five-point Likert scale

[1] 1 — on my own computer, 2 — on a friend's computer, 3 — at work, 4 — at the university, 5 — I do not have access
[2] 1 — very easy, 2 — easy, 3 — neutral, 4 — difficult, 5 — very difficult
[3] 1 — no cost, 2 — nearly no cost, 3 — acceptable cost, 4 — burdensome, 5— very burdensome
[4] 1 — without limitations, always, 2 — without limitations at work/at the university, 3 — no opinion, 4 — with limitations at work/at the university, 5 — always with limitations

Tab. 3. Main characteristics of the sample structure

Survey sample n = 347	
59.2% women	40.8% men
The distribution of employment status among the respondents:	
37.6%	not employed, not looking for a job (full-time students)
25.4%	employed, working 40 or more hours a week
19.7%	employed, working 1 – 39 hours a week
17.3%	self-employment etc.
The distribution of respondents' experience in work with AutoCAD:	
50%	using the software for six months
30.5%	more than six months, up to a year
15.8%	more than a year, up to five years
3.7%	more than five years

issue. It is, therefore, worth learning their preferences and opinions.

Women accounted for 59.2% of the survey sample (n = 347), and men — for 40.8%. In the economic reality of our days, it is not uncommon to meet an MSc student who is already working as an engineer. Therefore, it is worthwhile defining the distribution of the employment status among the respondents and the distribution of respondent experiences with AutoCAD. The main characteristics of the sample structure are presented in Table 3.

4.2. Method

The study is based on Structural Equation Modelling (SEM). Structural Equation Modelling allows to present the causal structure of phenomena statistically, where:

- many variables can be analysed concurrently,
- the analysed variables can be latent, which means they are not measured directly.

The relationships between the indicator variables are captured in a covariance matrix. The Structural Equations Model consists of two components. The first one — the structural model — describes dependencies between latent variables, while the second component — the measurement model — describes the value of observable variables. The process of structural modelling can be divided into consecutive stages (Hair et al., 2010; Charles & Kumar, 2014, p. 311):

- data collection;
- model specification;
- identification, which it comes down to answering the question, whether information included in the variance–covariance matrix is sufficient as a basis for estimating the model parameters;
- estimation — minimising a certain function of judging how well the model fits the empirical data (the maximum likelihood method is most commonly used);
- evaluation — comparing differences between the implied variance–covariance matrix and the sample variance–covariance matrix (the function of these differences has the distribution χ^2, which allows their significance to be assessed precisely, using an adequate statistical test[1]);
- modification of the structure of factors and items, if the model fit needs to be improved.

The statistical methods used for the empirical verification of validity and reliability include variance analysis and — first of all — Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA). In the confirmatory approach, a theoretical model is the starting point; otherwise, the approach is referred to as exploratory. In practice, these two approaches complement each other. Each exploration is based on an initial model (number of constructs, number of items). A similar process takes place in the confirmatory analysis, and if empirical verification does not support the model assumptions, they are usually modified to obtain a better fit.

[1] The research practice shows that model assessment should be based on measuring the value of many indicators (χ^2, statistics, TLI, Standardised RMR, RMSEA, etc.). Only adopting an approach like this enables the decision to be made whether the model fit is good enough or insufficient.

Tab. 4. Evaluation of the measurement model

Factor	Alpha	CR	AVE	PEOU	PU	BI	PPA	USE
PEOU	0.87	0.87	0.58	***0.76***				
PU	0.95	0.95	0.79	0.54	***0.89***			
BI	0.88	0.88	0,59	0.67	0.57	***0.77***		
PPA	0.84	0.80	0.51	-0.16	-0.26	-0.03	***0.71***	
USE	0.86	0.86	0.55	0.33	0.35	0.31	-0.36	***0.74***

Note: Chi-square (242) = 501.81; CFI = 0.94; TLI = 0.93; RMSEA = 0.056 (90% CI = 0.05-0.06); n = 347.
Values in bold and italic along the diagonal indicate the square root of the average variance extracted (AVE).

Individual scale items should be correlated to a high degree. The internal reliability of a scale[2] is most often tested by computing coefficient α proposed by Cronbach. Factor analysis of validity is based on two procedures (Charles & Kumar, 2014, p. 306):

- the analysis of principal components or the principal axis factoring used at the initial stage of the test;
- structural equations modelling (SEM) in a situation where dependencies between measures and factors are theoretically determined.

Using SEM for verifying measurement models is referred to as CFA. Confirmatory factor analysis confirms (or rejects) the hypotheses proposed a priori that specify dependencies between a set of items and individual constructs and at the same time is used for determining the adequacy of measurement scales: their validity and reliability. The procedure of determining the model validity consists of proving that the proposed model fits the data and that factor loadings are statistically significant (statistical value $|t| > 1.96$).

Fornell and Larcker (1981) proposed a simplified procedure for confirming validity based on average variance extracted (AVE), which is computed using the value of model estimated parameters as a basis. AVE takes a value from the interval [0; 1]. Validity is considered confirmed if AVE > 0.5, which means that more than 50% of the item variability is explained by the variability of the latent construct.

Causal relationships between items and latent constructs can be presented using reflective or formative indicators. Przechlewski (2011, p. 65) observes that in social sciences, latent features are much more often measured using the reflective approach, where the construct is considered as a cause and the item — as an effect. In formative indicators, causality takes an opposite direction, i.e. an item is a cause and a construct — the effect (Hair et al., 2010, p. 734).

[2] The internal reliability coefficient is defined as the average correlation coefficient value for individual scale items.

5. Results

For testing the structural model concerning the relationships among the variables, a path analysis was performed via SPSS and AMOS. The study was carried out following the stages described above. A two-stage analytical approach was adopted: during the first stage, the measurement model was tested for its reliability and validity. In contrast, during the second stage, a structural model was analysed to test the research model of the hypothesis.

5.1. EFA

Complete data (347 records) using SPSS were submitted for the EFA (Exploratory Factor Analysis). The analysis proceeded in an exploratory mode to determine how and to what extent the observed variables were linked to their underlying factors.

The obtained KMO (Kaiser–Meyer–Olkin) measure of sampling adequacy = 0.912 is excellent and indicates that patterns of correlations are relatively compact, and so, factor analysis should yield distinct and reliable factors (Charles & Kumar, 2014, p. 306). Bartlett's test (p-value = 0.000) is statistically significant.

5.2. CFA

Within the framework of SEM, the CFA (Confirmatory Factor Analysis) model represents what has been termed as a measurement model. This step tested if the empirical data confirmed the presumed model. The data obtained were tested for reliability and validity using confirmatory factor analysis. The results are presented in Table 4.

The data set provides sufficient discriminant validity because the square roots of all AVE scores are significantly larger than any other correlation coefficients among all constructs (Fornell & Larcker, 1981).

Tab. 5. Parameter estimates for causal paths

Structural path	Beta	t-value	p-value	Test result
H1. PEOU → PU	0.54	8.69	0.001	Supported
H2. PU → BI	0.31	5.54	0.001	Supported
H3. PEOU → BI	0.51	7.91	0.001	Supported
H4. PPA → BI	0.15	2.56	0.010	Supported
H5. BI→ USE	0.40	4.61	0.001	Supported
H6. PPA → USE	-0.40	-3.77	0.001	Supported

Note: Chi-square (245) = 486.36; CFI = 0.94; TLI = 0.94; RMSEA = 0.053 (90% CI = 0.05-0.06); n = 347.

5.3. Structural equation modelling (SEM)

The SEM model was drawn and then, the path structure of the conceptual model was computed using AMOS. The research model was tested with the maximum-likelihood estimation. The t-student statistics were reached, which allowed supporting each of the formulated hypotheses of this study. The obtained results are presented in Table 5. Standardised RMR = 0.0798 is correct because it should be < 0.08. Index Beta shows values of parameters that represent the regression coefficients among the constructs.

As shown in Table 5, all postulated relationships between the constructs were highly significant at $p < 0.001$, with one exception: the relationship between PPA and BI (referring to H4) was statistically significant at $p < 0.010$.

6. Discussion

The measurement model test presented a good fit between the data and the proposed measurement model. For instance, the comparative fit index (CFI) value was 0.944; CMIN/df = 1.985; TLI = 0.937; RMSEA = 0.053. According to Browne and Cudeck (1992), RMSEA value of 0.05 indicates a close fit, while a value of up to 0.08 represents a reasonable fit.

The internal reliability of the model was examined by inspecting Cronbach's alphas and composite reliability (CR). Cronbach's alphas for all variables and CR values were above the recommended level of 0.70 (Akkucuk, 2014; Zarantonello et al., 2015). These results confirmed that the internal consistency of the applied scales was acceptable with composite reliability ranges from 0.80 to 0.95.

The author also assessed convergent validity by measuring the average variance extracted (AVE). AVE measures the amount of variance for the specified indicators accounted for the latent construct. Higher variance extracted values occur when the indicators are truly representative of the latent construct. The guidelines recommend that the variance extracted value should exceed 0.50 for a construct (Sobh, 2010; Charles & Kumar, 2014; Zarantonello et al., 2015). The obtained values fulfilled the suggested levels with variance extracted value ranges from 0.51 to 0.79. This means the existence of sufficient convergent validity of all the measures. This information, together with the strong Cronbach's alphas, provides sufficient evidence for the internal consistency of the measurements.

The author also tested the emergent relationships between variables. Both the perceived ease of use and the perceived usefulness are important factors that encourage behavioural intention of AutoCAD use. The perceived usefulness effect was lower than that for the perceived ease of use. This may suggest that users are willing to accept software based on the ease of use rather than based on the functionalities it offers. One may assume that the CAD software available on the market has similar functionalities, but the ease of use is the feature the user values the most. It may be expressed through, e.g., a user-friendly interface and high intuitiveness of the application. This is consistent with the studies published earlier by Davis, who stated that: "a technology that is easier to use will be seen as more useful" (Davis et al., 1989). The perceived ease of use has the strongest effect on the perceived usefulness ($\beta = 0.54$, p-value = 0.001). A similar tendency was observed by Chintalapati et al. (2016) when analysing YouTube as a learning source in higher education.

The aim of the current study was to develop a more comprehensive version of the Technology Acceptance Model by adding a new variable — PPA. The intended purpose was to explain how the perceived physical accessibility of AutoCAD influences variables BI and USE.

The extended model assumes that PPA may have a positive impact on BI (H4. PPA → BI) because easy physical access to software (without any perceptible barriers, such as cost, time, place etc.) translates into

the positive attitude of a user towards AutoCAD. The second assumption concerns the influence of PPA on the USE, as per hypothesis 6 (PPA → USE). If AutoCAD is easily accessible (i.e., no barriers exit), this fact has a positive effect on the actual use of the application. A potential engineer with a certain design assignment and no oppressive or even prohibitive access barriers to AutoCAD, will certainly not be looking for any other CAD software even if the latter is more easily accessible. Users are perfectly capable of evaluating a piece of technology, and they will be using it, provided that benefits outweigh the cost. The tests show that the physical accessibility of software has a significant influence on the behavioural intention of the use of AutoCAD and its actual usage as well.

To sum up, all hypotheses (H1, H2, H3, H4, H5 and H6) received empirical support. The results of the study (Table 5) can be listed as follow:

- PEOU has a statistically significant effect on PU (H1) — this result suggests that when the perceptible satisfaction of users with the ease of use of AutoCAD grows, the perceived usefulness of the software increases as well. This key link is also revealed and confirmed by the state-of-the-art theories in the TAM;
- PU has a statistically significant relationship with BI (H2) — when the perceived usefulness of AutoCAD increases, the positive attitude of users towards the software becomes stronger as well;
- PEOU has a statistically significant effect on BI (H3) — when the perceptible satisfaction of users with the ease of use of AutoCAD grows, user intentions to use the software become stronger;
- PPA exerts a statistically significant impact on BI (H4) — when users do not experience barriers to AutoCAD accessibility, their positive attitude towards AutoCAD grows stronger;
- BI has a statistically significant effect on the USE (H5) — when the positive attitude of users towards AutoCAD grows stronger, the actual use of the application increases;
- PPA exerts a statistically significant impact on the USE (H6) — physical accessibility of the application (fewer access barriers) translates into its greater actual use.

Conclusions, limitations and future research

To the knowledge of the author, this was the first study to explore the TAM within the AutoCAD software context. It was also the first effort to empirically validate this extended model. The originality of the present study lies in examining the impact of perceived physical accessibility of AutoCAD on other factors in the TAM, using SEM framework, thus contributing to a new direction of research in the field.

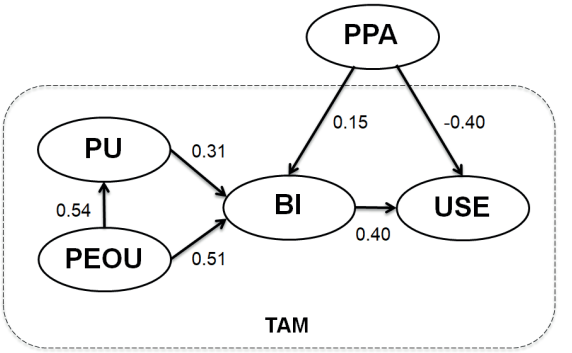

Fig. 2. Extended model TAM of the user attitude towards AutoCAD software with the path structure estimation

The proposed model (Fig. 2) shows the importance of the PPA variable (AutoCAD accessibility) and proves its significant effect on the variables BI and the USE. Thus, the empirical findings have demonstrated that adding PPA to the TAM model has been a worthwhile extension. The analysis proved that besides PU and PEOU, the PPA construct became another determinant of the AutoCAD adoption. The effect of PPA on BI and the USE seemed to be obvious but required empirical confirmation.

Business informatics lack commonly recognised measurement scales. The scales for measuring latent constructs PU and PEOU have been verified many times and are used in general. However, they were an exception in this case. As compared with psychology, for example, where SEM is used, achievements are not particularly impressive in the area covered by the subject of this study. For this reason, the fact of turning attention to such an important element as PPA, confirming its effect on BI and the USE and developing adequate measurement scales was the added value contributed by this study.

The research project presented here was subject to certain limitations that should be considered. Namely, a high share of students in the research sample was one of the major limitations. Possibly, the findings might have differed with proportional representation of different age groups. Possibly, older and more "mature" respondents could have shown more experience with and competence using AutoCAD. Hence, should one change the respondent selection criterion from a few months to a few years of work with this software, the research results might be different. Students, often used as convenience sample respondents in TAM stud-

ies, are not exactly like either of the other two groups: professionals and general users. Yet, considering the work by King and He (2006), one may assume that students may be used as substitutes for professional but not "general" users. The author should like to emphasise that the sample for the current study was selected respecting this finding.

The primary objective of the study was to extend the basic TAM model by adding the PPA variable. The focus of future research will be on further expansion of the model by incorporating other variables and testing different IT, as well as by considering different areas of TAM application.

Finally, it would be interesting to investigate the proposed model under different conditions to check its functionality.

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Structured Problem Solving: combined approach using 8D and Six Sigma case study

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ABSTRACT
The current research study aimed to explore the utility of selected problem-solving tools and techniques in root-cause analysis to demonstrate their practical application. An experimental research design adopting a positivist empirical approach with a deductive strategy was followed to assess the effectiveness of a combined (8D & Six Sigma) problem-solving approach in reducing a high defects rate of a mixer shower assembly line. A novel application of the 8D framework in combination with Six Sigma and other analytical tools was found highly effective in reducing the reject rate from 11.84% to 0.11%. Successful identification of the root cause led to the implementation of permanent corrective action ensuring a long-term stable assembly process. The research study provided a problem-solving framework that was found effective in resolving a complex problem and implementing long-term corrective action in an assembly production line. However, this framework can be used in other industries. The research study provides a solution to a high number of leak rejects in a sub-assembly where "O-seals" are used between mating parts. It also provides analytical tools that were found highly effective during the problem-solving process.

KEY WORDS
8D, Six Sigma, Structured Problem Solving, customer complaints, defect reduction

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Introduction

In today's ever-evolving challenging times, the problem-solving skillset is one of the most desired attributes (De Fruyt, Wille & John, 2015) in any industry. Problem-solving is at the core of human evolution. It is the method used by humans to understand what is happening in their environment, identify things to be changed and then establish adjustments that are required for achieving the desired outcome. Problem-solving is the source of all new inventions, social and

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cultural evolution, and the basis for market-based economies. It is the basis for continuous improvement, collaboration and learning. It is, however, well known that stressful circumstances may induce impulsive solution-seeking without gaining adequate insights into the nature of a confronted problem. Based on a survey of 106 C-suite executives representing 91 private and public-sector companies in 17 countries, it was found that 85% of the population sample perceived that their organisation's problem diagnosis skills were bad; and 87% reported that a failure to identify an accurate problem incurred significant costs (Wedell-Wedellsborg, 2017). One of the prime reasons for an organisations' struggle with problem diagnosis is the lack of time and effort required for a rigorous diagnostic procedure. Many popular existing frameworks, such as Six Sigma, TRIZ, TQM, Scrum, and others, are very comprehensive and directed in terms of complex problem-solving. However, for day-to-day issues where quick turnaround is imperative, the thoroughness of their procedures become a limiting factor. Furthermore, for an effective application of these frameworks, specialised training and working experience is statutory, which may impose a further hindrance. There are other structured problem-solving frameworks, such as Eight Discipline (8D) or A3, that can be used for quick turnaround time. Several applied research studies have been conducted in the area of 8D framework and its application in the mostly automotive industry. The study presented in the article explores a novel combined approach of 8D framework with key analytical tools from the Six Sigma methodology and popular industrial techniques in resolving a complex engineering issue with reasonable turnaround time. Next, the study explores the utility of commonly used analytical tools for the assembly processes of the plumbing industry.

This research study was conducted in a UK-based, global plumbing company, renowned for its bathroom products. A soon-to-be-launched mixer shower product was demonstrating a high reject rate for leak failures. The product consisted of 12 key sub-assemblies and components, which went through five assembly stations, and two leak tests at different stages of assembly. At the final leak stage, approx. 12% of the product was rejected for a high leak rate resulting in a high financial loss due to scrap and re-work. The research study aimed to reduce high leak rejects using a combined approach of the 8D framework in combination with Six Sigma and other analytical tools for root-cause analysis.

1. Literature review

Problem-solving is at the core of human evolution. It is the basis of all new inventions, social and cultural evolution, continuous improvement, collaboration and learning. The evidence for its relevance can be found in prehistoric stone tools available in the archaeological record, those made between 2.5 and 1.5 million years ago in East Africa, which led to the emergence of a new cultural era (Leaky, 1971; Toth, 1985); and Nanorobots created by the University of Pennsylvania that revolutionised the field of medicine and health by performing surgeries and delivering medicine (Carne, 2019).

So, what is problem-solving? It is the act of defining a problem; determining the cause of a problem; identifying, prioritising and selecting alternatives for a solution; and implementing a solution (Riesenberger & Sousa, 2010). Each step in the problem-solving process employs skills and methods that contribute to the overall effectiveness of influencing change and determine the level of problem complexity that can be addressed. Humans learn how to solve simple problems from a very early age (learning to eat, make coordinated movements and communicate) — and as a person goes through life, problem-solving skills are refined and matured into more sophisticated versions enabling them to solve more difficult issues. Problem-solving is important both to individuals and organisations because it allows exerting control over the environment. Some of the most popular problem-solving frameworks in the manufacturing industry include Six Sigma, TRIZ (Teoriya Resheniya Izobreatatelskikh Zadatch/Theory of Inventive Problem Solving) and TQM (Total Quality Management).

Six Sigma is a systematic set of guidelines that aims to significantly improve the quality of a manufacturing process and reduce costs by minimising the process variation and reducing defects. It utilises statistical tools that can either be applied to facilitate a new product development or strategic process improvement (Breyfogle et al., 2001). In the last decade or so, there has been a rapid uptake of the Six Sigma technique as a process change, management and improvement strategy by global industries. This helped them beat market competition and maximise yearly savings (Su & Chou, 2008; Yang & Hsieh, 2009). Besides, in the last decade or so, there has been a massive uptake and implementation of the Six Sigma technique as a process change, management and improvement strategy by global industries, which include the manufacturing process (Al-Aomar, 2006; Gangidi, 2019; Valles et al.,

2009), financial organisations (Brewer & Eighme, 2005), engineering firms (Bunce et al., 2008), hospitals and intervention clinics (Craven et al., 2006; Olszewska, 2017), banking, hospitality, pharmaceutical companies (Cupryk et al., 2007), chemical industries (Doble, 2005), educational institutions (Bandyopadhyay & Lichtman, 2007), the software industry (Arul & Kohli, 2004), call centres (Schmidt & Aschkenase, 2004), utility service providers (Agarwal & Bajaj, 2008), the automobile sector (Gerhorst et al., 2006), information technology (Edgeman et al., 2005), human resources departments (Wyper & Harrison, 2000), military administration units (Chappell & Peck, 2006) and even government departments (Furterer & Elshennawy, 2005).

Another popular problem-solving tool TRIZ is considered to be an avant-garde, knowledge-based problem-solving technique (Savranksy, 2000). TRIZ has been argued to serve the dual purpose of new product or systems development as well as provide a set of guidelines for an enhanced understanding of the evolution of technologies and systems (Fey & Rivin, 2005). It has also been referred to as a toolkit for one of the most rigorous, scientifically organised and sweeping understanding of all aspects of creative problem solving, which gets TRIZ an edge over other innovative problem-solving methods (Gadd, 2011; Livotov, 2008). For instance, other known tools of brainstorming, mind mapping, morphological analysis etc. hold the potential to reveal the root cause of a problem but fail to lead to an effective solution. TRIZ offers innovative solutions when all the possible alternatives have been exhausted and the new exposition can be accepted with confidence (Gadd, 2011). Since its inception in Russia, with mere two institutes for TRZ training (Souchkov, 2008), it has now spread to over 35 countries and is a part of course curriculum across numerous reputed universities as well as part of strategic policies in global companies, such as Ford Motors, Procter & Gamble, and Mitsubishi (Rantanen & Domb, 2008).

Yet another influential quality movement that revolutionised problem-solving across industries was Total Quality Management (TQM). TQM was conceptualised and invented in Japan (Cole, 1998; Esaki, 2016; Juran, 1995) as a means of overcoming the loopholes in contemporary investigative techniques. TQM is considered to be an organised strategy emphasising the evidence-based systematic procedure, including the top-down management hierarchy, staff engagement, and inclusion of customer requirements while decision making (Tobin, 1990). The flip side of the coin in this context is that the scope of TQM is too broad and a variety of definitions are possible, which increases the probability of making ineffective permutations of its possibilities, lowering the consistency and reliability of its use just as has been reported in the manufacturing industry (e.g., Andersson et al., 2006; Boaden, 1997; Brown et al., 1994; Eskildson, 1994; Cao et al., 2000; Nwabueze, 2001; Talapatra, Uddin & Rahman, 2018; Sebestova, 2016). Evidence from independent publications indicated that two-thirds of TQM implementation efforts failed to produce any significant improvements in product quality or the financial, competitive situation of a company (Jimoh et al., 2018). The biggest challenge in applying these technical, rigid problem-solving frameworks is the required knowledge and expertise to use them effectively and efficiently across a range of scenarios, in particular for TRIZ (Wedell-Wedellsborg, 2017; Ilevbare, Probert, & Phaal, 2013). A comparative summary of the three problem-solving tools discussed in the above section is shown in Table 1.

For the current research scenario, the concerned product was facing a complex issue of high leak rate with a high variation in the assembly process; thus, Six Sigma was deemed to be most appropriate in resolving it. However, as the product was close to the launch date, a quick turnaround strategy demanded a less rigorous methodology than Six Sigma. Therefore, the 8D framework was explored as an additional problem-solving tool. As a cogent methodology, 8D is designed for the identification of a problem, tracing its root cause, creating a containment fix and further implementing a long-term solution to prevent the recurrence of the problem. Its characteristics make it an excellent choice as a first step in improving the quality and reliability of a defective product that may be causing customer dissatisfaction. Its effectiveness is evident from its use during the World War II by the US government, wherein it was referred to as Military Standard 1520, which means a corrective action and disposition system for nonconforming material (Berk, 2000). The origins of the 8D methodology can be traced back to 1987 when the Ford Company first documented its use in a manual titled "Team Oriented Problem Solving (TOPS)", by the request of the senior management team who were confronting a series of recurring problems for the Power Train organisation of the automaker (Behrens, Wilde & Hoffmann, 2007). It was found to be so effective, easy to use and reliable that 8D was officially nominated as the primary method for documenting problem-solving efforts at the Ford Motors and it is still used today. Following Ford, many other manufacturing companies adopted this technique in their toolkit. Some of the case studies are presented in Table 2.

Tab. 1. Comparative summary of structured problem-solving tools

Concept	Origin	Aim	Focus	Methodology and Tools	Criticisms
Six Sigma	Motorola Inc. (1987)	Improve process capability	Reduce process variation by controlling inputs	Methodology: DMAIC Tools: Statistical techniques	Skilled workers required to implement, resource-demanding and long-term
TRIZ	Russia (the 1940s)	To develop inventive solutions to complex problems	To understand contradictions and resolve them	Methodology: Tools: Contradiction Matrix, ARIX	Difficult to acquire, training, resource-demanding
Total Quality Management (TQM)	Japan (the 1990s)	Improve the quality and consistency of processes	Customer satisfaction	Methodology: Plan Do Study Act Tools: Statistical techniques	Vague and inconsistent conceptualisation, excessive resource consumption, unsatisfactory results

Tab. 2. Case summary for the application of the 8D methodology

Authors	Name of an organisation	Benefits of implementing the 8D methodology
Behrens, B. -A., Wilde, I. and Hoffmann, M., 2007; Rambaud 2006	Ford & Suppliers	The 8D methodology started with the Powertrain Organisation of the Ford Group. With benefits seen from the team-oriented problem solving (TOPS), it was rolled out business-wide. Soon entire Ford supply chain, including suppliers, were using the 8D framework
Whitfield, R. C. and Kwok, K. -M., 1996	Hongkong based Electronics company	Improving the quality of the Integrated assembly line using Ford's 8D methodology. Highlights the benefits of highly focused approach with simple analytical tools of 8D in achieving considerable benefits in a short time
Saidin, W.A.N.W., Ibrahim, A.M., Azir, M Ngah, H., Noor N. M. and M.H Norhidayah., 2014	Automotive Company (Trim Line)	Significant reduction in defect rate of the highest failure on Trim area resulting in financial gains. 8D offers an essential solution from identifying the root cause until the implementation of preventive action. Quick turnaround time and easy to implement the methodology

2. Research methods

The overall aim of the research study was to reduce the number of high leak rejects during the manufacturing and assembly process of a mixer shower. As it was a complex engineering problem with a high variation in the manufacturing/assembly process, the Six Sigma methodology was deemed most appropriate. However, as immediate protection to the customers and quick resolution of the problem was required, the 8D framework combined with key analytical tools from the Six Sigma DMAIC methodology was deemed most appropriate in resolving the issue with a quick turnaround. Step-by-step elucidation of the intricacies in terms of appropriate conditions for implementing it and the procedural details are listed below, in nine stages (Rambaud, 2006):

- D0: Plan to solve the problem and determine its prerequisites. 8D is a fact-based problem-solving process involving specialised skills and a culture that favours continuous improvement (Duffy, 2013). Additional education and training were provided to identified team members.
- D1: Utilise available resources. A cross-functional team of people who already possess some degree of product/process knowledge were selected.
- D2: Define and describe the problem. The problem was defined in quantifiable terms of 5W2Hs: who, what, where, when, why, how, and how many for the issue of concern.
- D3: Develop an interim containment plan; implement and verify interim actions. At this stage, risks to various customers were identified, and appropriate containment actions were implemented, verified and refined to protect the customers.
- D4: Determine, identify, and verify root causes and escape points. Brainstorm and explore all the possible causes that could explain why that problem might have occurred. Also, detect the reason for the failure to identify the early occurrence of the problem. It is important that any derived hypotheses are scientifically justified and adequately documented. An effective tool for this purpose is the Five Whys and cause-and-effect diagrams to map causes against the effect or the identified problem. Further, key tools of Measure,

Analyse and Improve the phase from the DMAIC methodology of Six Sigma were utilised in this research study to enhance the validity and sustainability of the implemented solutions. Another popular analytical technique of component search analysis was also used for the root-cause analysis.

- D5: Choose and verify permanent corrections (PCs) for the problem/nonconformity. The proposed solution was evaluated quantitatively through pilot programmes ensuring the problem was resolved for the target customer.
- D6: Implement and validate corrective actions. The best corrective actions (CA) were developed and implemented during this stage.
- D7: Take preventive measures. Transfer lessons learnt to modify the management systems, operation systems, practices, and procedures to prevent recurrence of such problems.
- D8: Congratulate your team. Recognised the team which will act as a motivator and facilitate sustainable changes across the organisation.

3. Research results

Structured problem solving was designed by using a combination of 8-Discipline and the Six Sigma methodology together with key industry-standard analytical tests. The identified problem was diagnosed as a high number of leak rejects from a mixer shower assembly line, which could result in significant financial losses and tarnish the company's reputation, if the product would hit the market with this defect. The entire process of structured problem-solving was split into nine key stages as delineated in the methodology section above. Specifics of each stage for the current scenario are discussed below:

D0: Prepare and Plan for the 8D. The initial evaluation of the problem suggested the appropriateness of using the 8D framework together with the Six Sigma methodology. During this stage, preparations were made to initiate the problem-solving process, and adequate training was delivered to the concerned personnel.

D1: Form the team. A cross-functional team was formed from representatives of design, manufacturing, operations, supply chain (purchasing & supplier quality assurance) and quality departments. It was further ensured that they were competent in the 8D framework and the Six Sigma methodology.

D2: Describe the Problem.

The first step was to collect initial data related to the problem with the help of "Is/Is Not" analysis. Historical data demonstrate that the mean daily failure rate is 0.1184 or 11.84% with no clear trend (Fig. 1). Once the necessary information was available, the following problem statement was generated: "11.84% of the finished products failed the Shutoff Leak Test for Product X Line, which resulted in re-work/scrap."

A scoping diagram was created for the initial project scoping, which helped to focus problem-solving efforts towards 11 key areas (Fig. 2). Items found to be outside the scope in this step were still considered to be relevant for further investigation during the 2nd iteration of the problem-solving process. However, the process terminates at this step if the root cause gets identified.

D3: Containment. During this stage, the main focus was to protect an external and internal customer. The review of failure using the FMEA strategy revealed that chances of a faulty product escaping the assembly line were negligible as it would have been detected by the end of the line quality checks. The initial containment was to reject and quarantine a faulty product for an engineering investigation. At this stage, an external customer was fully protected; however, scrap parts from the rejects incurred cost and throughput risks for the internal customer (Production & Engineering). The initial RCA work discussed in the next section suggested that the re-working of the product could be the next stage of containment. As RCA work further progressed, it helped to refine the re-work process by creating a clear and simple re-work procedure, which fixed the majority of the rejected products. The re-work was to replace housing, send it for a leak test, and if a part gets rejected again, manually file the split lines and send for a leak test again.

D4. Root-Cause Analysis (RCA). During this phase, some principles from the Six Sigma methodology, especially the techniques used in the "Measure, Analyse and Improve" phase of Six Sigma were used. Further common tools and techniques used in the industry were also employed. As a first step, the measurement equipment used for measuring the Key Process Output Variable (Leak Rate) was validated. Annual Gage R&R was successfully completed with daily checks. The use of the artefact standard was also found to be within control limits and high Cgk of 1.51, as shown in Fig. 3.

Drawing on insights gained from the initial investigation and historical data, a four-staged "Component Search" analysis was conducted on the sub-assembly to

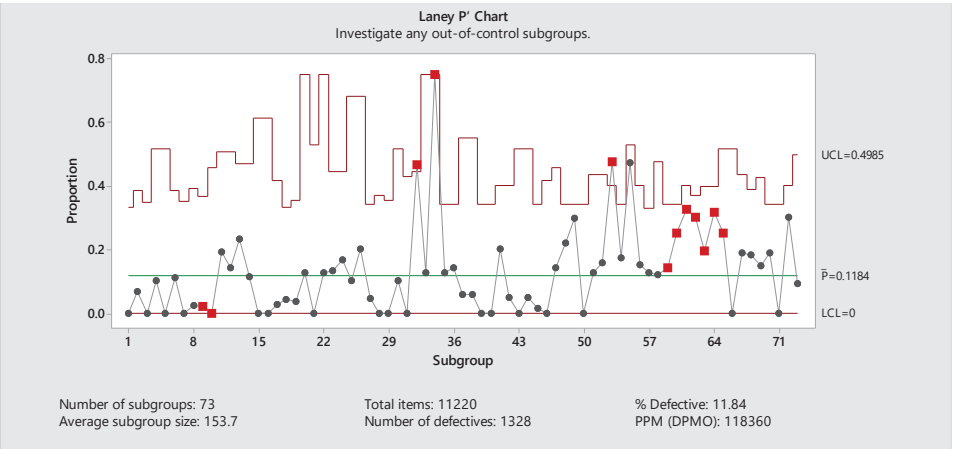

Fig. 1. Proportions control chart showing the daily reject trend

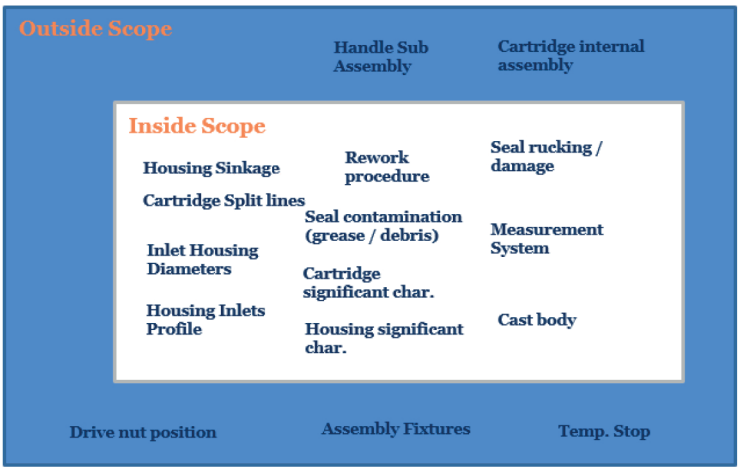

Fig. 2. Scoping diagram

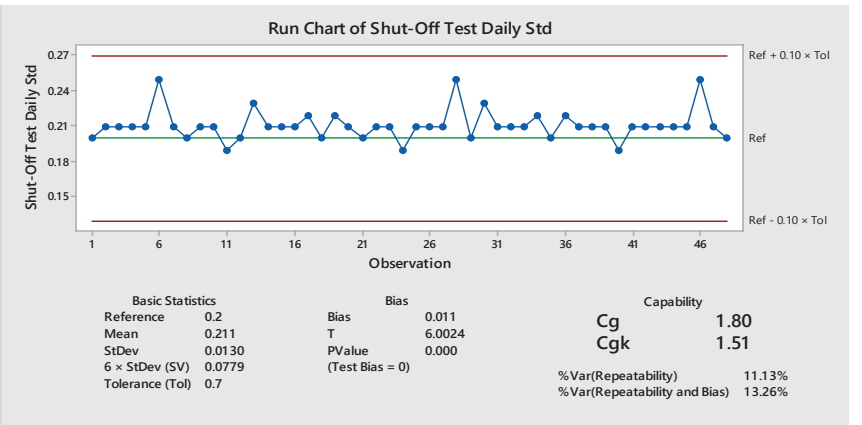

Fig. 3. Capability report for leak Rate Measuring Equipment

identify, which component was faulty. A step-by-step procedure is presented below:

Stage 1. One best and one worst product were sampled. They were built and rebuilt three times and measured for the Measurable Customer Response, which was the leak rate in this case. From this data, the upper and lower decision limits were calculated using statistics, as shown in Table 3.

Stage 2. Key components were swapped one at a time between the best and the worst samples. After every component swap, samples were measured again for the leak rate. Leak rate results for housing and cartridge swap fell outside the decision limits, indicating that they were important components for the leak rate.

Stage 3. Both important components (housing and cartridge) were then swapped together between the

Tab. 3. Component search analysis results from Stages 1 and 2

Test Description	Best	Worst	High Lower Decision Limit	High Upper Decision Limit	Low Lower Decision Limit	Low Upper Decision Limit	Analysis
Initial	0.21	1.88	0.1335	0.2865	1.8035	1.9565	
First Rebuild	0.25	1.85	0.1335	0.2865	1.8035	1.9565	
Second Rebuild	0.2	1.9	0.1335	0.2865	1.8035	1.9565	
Stage 2: Replace							
Cast Body	0.2	1.85	0.1335	0.2865	1.8035	1.9565	Not important
Housing	0.6	1.72	0.1335	0.2865	1.8035	1.9565	Important, so is something else
Cartridge	1.65	0.4	0.1335	0.2865	1.8035	1.9565	Important, so is something else
Brass Nut	0.19	1.86	0.1335	0.2865	1.8035	1.9565	Not important
Cartridge Top Seal	0.2	1.89	0.1335	0.2865	1.8035	1.9565	Not important
Cartridge Bottom Seal	0.22	1.9	0.1335	0.2865	1.8035	1.9565	Not important
Housing Face Seals	0.25	1.88	0.1335	0.2865	1.8035	1.9565	Not important

Tab. 4. Component Search Analysis results from Stage 3

Test Description	Best	Worst	High Lower Decision Limit	High Upper Decision Limit	Low Lower Decision Limit	Low Upper Decision Limit	Analysis
Stage 3: Replace							
Housing & Cartridge	1.88	0.22	0.1335	0.2865	1.8035	1.9565	2 important factors explain the variation

best and the worst samples and measured for the leak rate. Based on the results, the previously best sample was then the worst sample and vice versa (Table 4) suggesting that these two components (housing and cartridge) were responsible for the most variation found in the leak rate.

Stage 4. The main effect and interaction plots in Minitab software were generated using data from the previous stages (Fig. 4). These two components were significant, but the interaction between them was not clear.

The next step was to identify the specific parameter within these two components that might have been critical for failures. Paired comparison using Tukey test was performed. Key parameters that define or could affect failures were identified, twelve in total. Then, eight good and eight bad products were selected and measured for these twelve key parameters. Results from the paired comparison using Tukey test are shown in Tables 5 and 6.

Results from the paired comparison test found two parameters to be statistically significant for high

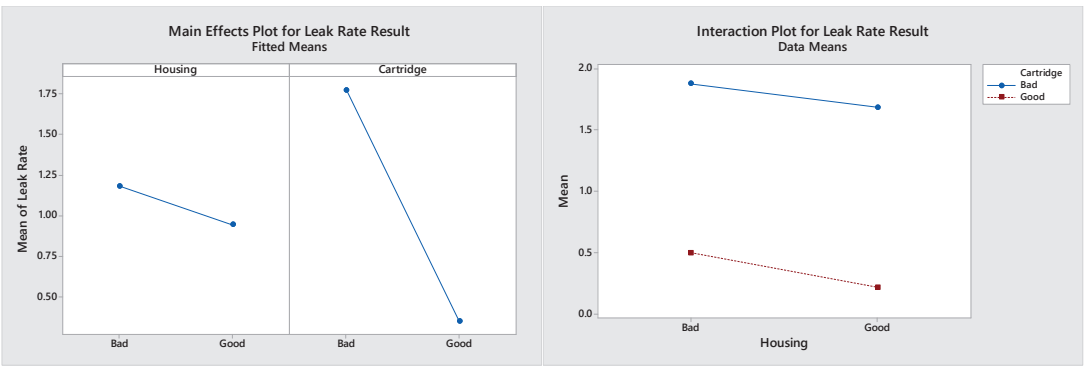

Fig. 4. Main effect and interaction plots for housing and cartridge

Tab. 5. Paired comparison (sorted results) for key parameters of the housing

Housing Bottom Diameter (mm)		Housing Bottom Roundness (mm)		Housing Bottom Concentricity (mm)		Housing Top Diameter (mm)		Housing Top Roundness (mm)		Housing Top Concentricity (mm)	
Bad	29.665	Good	0.077	Bad	0.049	Good	32.432	Good	0.142	Good	0.025
Good	29.667	Good	0.078	Good	0.13	Good	32.435	Good	0.142	Good	0.026
Good	29.667	Bad	0.079	Bad	0.136	Bad	32.44	Bad	0.145	Bad	0.027
Bad	29.668	Bad	0.082	Good	0.161	Bad	32.44	Bad	0.146	Bad	0.027
Good	29.669	Good	0.084	Bad	0.162	Good	32.44	Bad	0.148	Bad	0.027
Good	29.67	Good	0.088	Bad	0.163	Good	32.442	Good	0.142	Good	0.028
Good	29.67	Good	0.088	Bad	0.163	Bad	32.442	Bad	0.145	Good	0.028
Bad	29.67	Bad	0.089	Good	0.163	Bad	32.442	Good	0.145	Bad	0.029
Bad	29.67	Bad	0.092	Bad	0.164	Bad	32.442	Good	0.153	Good	0.029
Good	29.671	Good	0.093	Bad	0.164	Good	32.442	Good	0.154	Good	0.03
Bad	29.671	Bad	0.093	Good	0.167	Good	32.443	Good	0.181	Bad	0.03
Bad	29.671	Bad	0.095	Good	0.168	Good	32.443	Good	0.187	Good	0.031
Bad	29.671	Good	0.098	Good	0.172	Bad	32.444	Bad	0.19	Bad	0.032
Bad	29.672	Good	0.104	Bad	0.173	Bad	32.445	Bad	0.198	Bad	0.033
Good	29.674	Bad	0.111	Good	0.175	Bad	32.453	Bad	0.2	Good	0.049
Good	29.674	Bad	0.124	Good	0.176	Good	32.454	Bad	0.201	Bad	0.065
Top EC	1		2		1		2		2		2
Bottom EC	2		2		2		0		4		1
Total EC	3		4		3		2		6		3
% Confidence	None		None		None		None		90%		None

Tab. 6. Paired comparison (sorted results) for key parameters of the cartridge

Cartridge Bottom Diameter (mm)		Cartridge Bottom Roundness (mm)		Cartridge Top Diameter (mm)		Cartridge Top Roundness (mm)		Cartridge Top Split-lines (mm)		Cartridge Bottom Split-lines (mm)	
Good	26.342	Bad	0.053	Good	28.309	Good	0.097	Good	0	Good	0.01
Good	26.349	Good	0.057	Good	28.31	Good	0.102	Good	0	Good	0.01
Bad	26.351	Bad	0.059	Good	28.311	Good	0.106	Good	0.01	Good	0.01
Bad	26.357	Good	0.06	Bad	28.315	Bad	0.108	Bad	0.015	Bad	0.015
Bad	26.358	Bad	0.061	Good	28.315	Bad	0.109	Bad	0.018	Bad	0.018
Good	26.364	Good	0.063	Good	28.315	Good	0.109	Good	0.019	Good	0.018
Bad	26.366	Good	0.065	Bad	28.316	Bad	0.109	Bad	0.021	Bad	0.018
Good	26.369	Good	0.073	Bad	28.317	Good	0.111	Good	0.021	Good	0.019
Good	26.371	Good	0.073	Bad	28.319	Good	0.112	Good	0.022	Bad	0.019
Bad	26.372	Bad	0.084	Bad	28.32	Good	0.12	Good	0.025	Bad	0.02
Bad	26.373	Bad	0.086	Bad	28.32	Bad	0.132	Good	0.03	Good	0.02
Good	26.375	Bad	0.087	Bad	28.32	Bad	0.134	Bad	0.035	Bad	0.021
Good	26.378	Bad	0.091	Good	28.321	Bad	0.137	Bad	0.038	Bad	0.025
Bad	26.38	Good	0.091	Bad	28.322	Bad	0.139	Bad	0.041	Good	0.028
Bad	26.383	Bad	0.095	Good	28.337	Good	0.139	Bad	0.045	Good	0.028
Good	26.39	Good	0.115	Good	28.344	Bad	0.144	Bad	0.051	Bad	0.03
Top EC	2		1		3		3		3		3
Bottom EC	0		1		0		1		5		1
Total EC	2		2		3		4		8		4
% Confidence	None		None		None		None		>95%		None

leak rates and failures, namely, roundness at the top half of the housing and also the top cartridge split lines. Closer scrutiny of this data revealed another layer of difficulty: that the top radial seal was failing to perform adequately that was resulting in leaks. The top split line was another significant parameter, but all the data was within specification and wasn't a problem on other similar products. To further investigate this issue, profiling of both housing and cartridge was conducted, the results of which are shown in Fig. 5 and 6.

Two spikes seen on the cartridge profile are split lines. The housing profile shows that it is oval in shape and provides less seal compression around the split lines region and more compression at +/- 90 degrees of split lines. This analysis revealed yet another cause for high leak rates, which were higher split lines and oval housing.

D5. Choose and Validate Permanent Correction. As discussed in the previous section, two key parameters were found responsible for a high leak rate or rejects. Firstly, it was top cartridge split lines that needed to be less than 0.05 mm to reduce leak rejects, but it was almost impossible to achieve this through the injection moulding process. The other option was to increase the seal compression around the split line region by improving the roundness of the housing. Before introducing the change, to ascertain that housing roundness was the most significant factor, two quick tests were conducted using the existing resources. Before starting the test, ten worst samples were created and measured for the leak rate to establish the reference condition. The first experiment was to replace the oval housing of these ten parts with a machined metal housing having good roundness. The second test was to rotate the existing oval housings by 90 degrees to give an increased seal compression around split lines. Leak rate results from all three conditions are shown in Fig. 7.

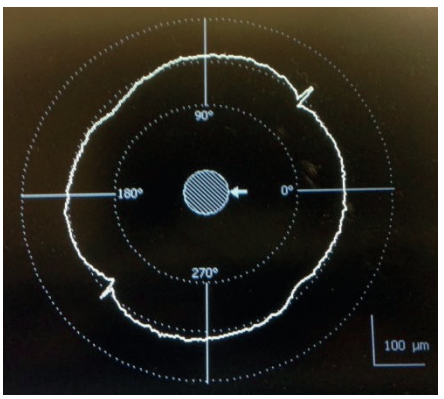

Fig. 5. Cartridge top-sealing face profile

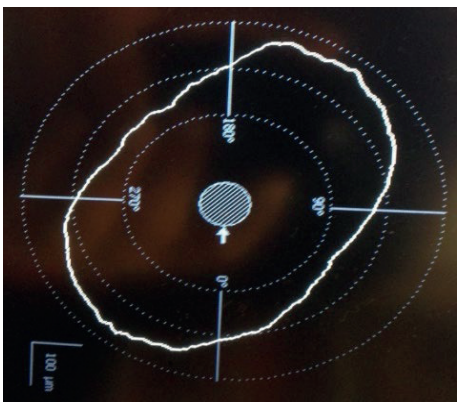

Fig. 6. Housing top-sealing face profile

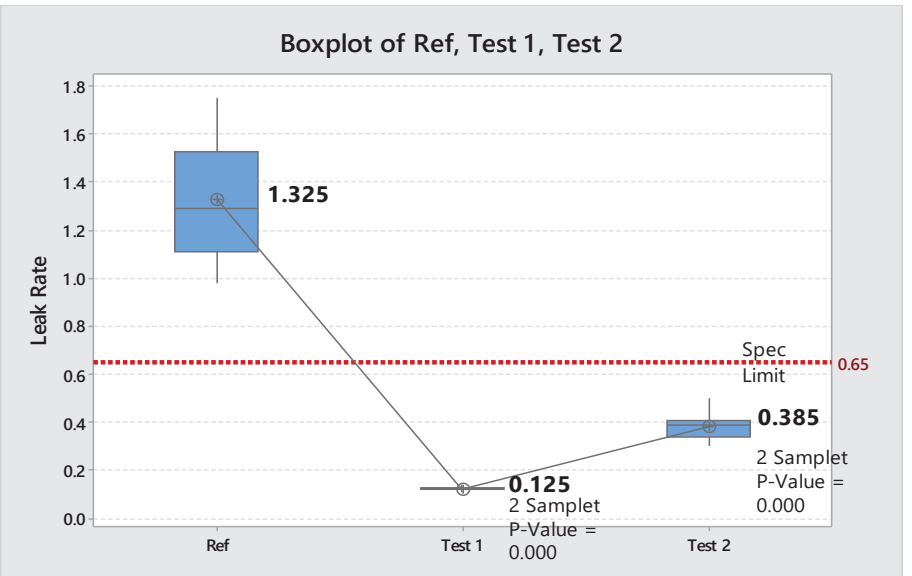

Fig. 7. Comparison among different test conditions

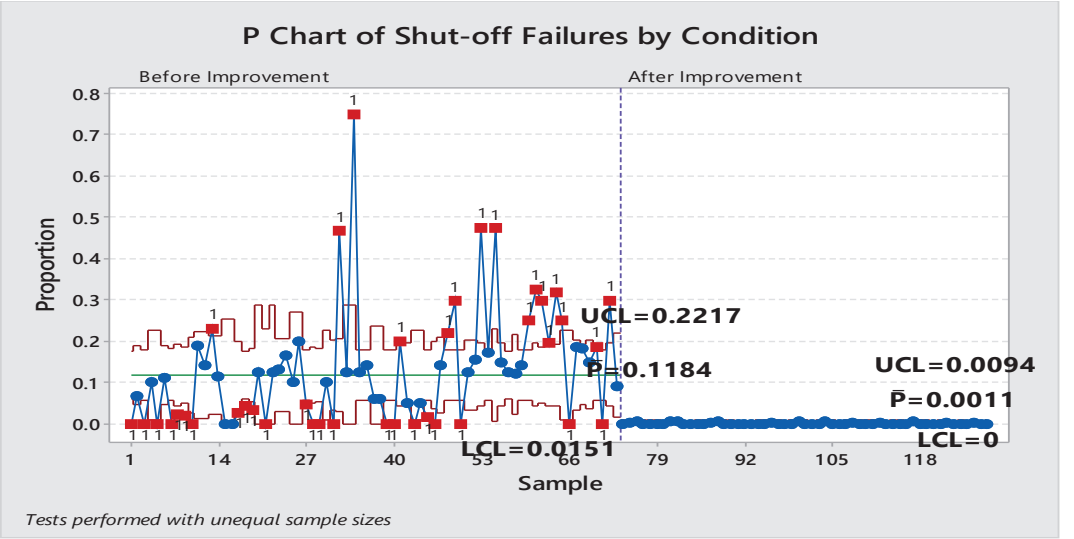

Fig. 8. Impact of PCA through P Chart of shut off failures

Both test conditions were statistically better than the reference. So, by improving the roundness of housing or increased compression around split lines, the leak rate can be reduced, thereby eliminating the failures.

D6. Implement and Validate the Permanent Corrective Action. Permanent corrective action was to improve the housing roundness with injection moulding supplier. From previous data analysis conducted during the RCA phase, an upper specification limit of 0.075 mm was applied to the housing roundness. A significant reduction in shut-off failures from 11.84% to 0.11% was observed after the improved condition, as shown in Fig. 8.

D7. Prevent Recurrence. To prevent recurrence of the failure mode, Design FMEA and Control Plan were updated. Detailed feedback on the lessons learnt and new knowledge acquired regarding the specific issue in the current organisation was also shared with the rest of the new and current product development team.

D8. Closure and Team Celebration. The results of the project and the team's achievement were shared with a wider audience using a company magazine and various departmental monthly meetings.

4. Discussion of results

The current implementation of the 8-Discipline framework combined with the Six Sigma methodology along with key industry-standard analytical tests proved successful against key project deliverables. The issue of a high leak-reject rate was clearly defined, thereby effective immediate containment was applied to reduce the impact on key stakeholders. Consistent with evidence of previous research (Mishra, 2018; Wedell-Wedellsborg 2017; Pyzdek, 2003), defining the problem is critical to achieving a permanent resolution of the issue. Defining the problem during the D1 stage largely consisted of ensuring that the team members understood the nature of the problem and what was expected of them, and spending time on developing a clear problem statement helped all team members to work towards a common goal and channel efforts in the right direction, avoiding any ambiguity or confusion.

The research study found that as progress was made through the 8D process, initial/interim containment that was put in place could be further refined. Initially, to prevent a faulty product reaching a customer, all parts were rejected and quarantined. Gaining insights into the issue through the D4 stage using Six Sigma statistical tools and component-search analysis, it was found that re-working the cartridge sub-assembly could reduce the failure rate. So, the second interim containment, which was to change the housing and cartridge one at a time, was created, which helped to reduce the number of rejected products. But it created another problem with the re-work cost that included re-work time and rejected components. As RCA investigation progressed further, the 3rd interim containment was introduced to re-work (file) the split lines on the cartridge. This reduced the re-work time and eliminated the cost of rejected components. As RCA and developing permanent

corrective action can take some time, it is advisable to refine or further develop interim containment action to reduce the impact of the problem. This was a novel finding.

Previous studies have shown that both 8D (Riesenberger & Sousa, 2010; Kaplík et al., 2013) and Six Sigma (Swarnakar, Vinodh & Antony, 2016; Ghosh & Rao, 1996) were highly effective in identifying the root cause of the problem and developing a permanent corrective action accordingly. Generally, 8D is used for less complex problems with quick response time, and Six Sigma — for more complex issues. However, there is a scarcity of studies on the benefits of combing the two approaches together to resolve complex problems with quick turnaround time. During the research study, Six Sigma statistical tools were used during D4, namely, the root-cause analysis part of 8D was used to resolve a relatively complex problem. The entire process from the problem identification to implementing a permanent corrective action tool only eight weeks with a couple of weeks added to verify the permanent corrective action. Generally, an 8D project takes three months, and a Six Sigma project takes six months to complete. It was found that this combined approach achieved the best result compared to both separate methodologies and resulted in a resolution of a complex problem within three months.

In line with previous research studies, 8D (Riesenberger & Souza, 2010; Laurie, 2006) and Six Sigma (Swarnakar, Vinodh & Antony, 2016) prevent recurring failures. The cost of recurring failures has a major financial impact on the company as well as results in customer dissatisfaction Based on the current research study results, it can be argued that the current methodology helped to prevent the recurrence of failures as the assembly line has been running for a year now without a recurrence of this failure mode.

It can be argued that the combined methodology used in this research study is relatively easy to use, but some basic training is essential. As suggested by other authors (Wedellsborg, 2016; Rebecca, 2018), some basic understanding of the 8D framework and the Six Sigma methodology is necessary to effectively solve the problems. For these reasons, team members with no prior hands-on experience of 8D received half a day training with regular mentoring throughout the project. Further, specific tasks requiring Six Sigma skillsets were conducted under the guidance of a certified Six Sigma Black Belt expert.

Limitations

It has only been a year since permanent corrective actions were implemented. It is a reasonable length of time to make conclusions, but more data need to be collected in terms of the number of research studies and the length of time to further enhance confidence.

Conclusions

The aim of the study was to reduce a high number of leak defects from the mixer shower assembly line in the bath & shower industry using a combination of 8-Discipline and the Six Sigma methodology together with key industry-standard analytical tests. It was a novel application as previously, 8D and Six Sigma had been implemented independently across several industries, such as finance, service, manufacturing and non-manufacturing, but never together for the mixer shower production in the bath & shower industry. A significant reduction in rejects from 11.84% to 0.11% was achieved within pre-defined time constraints. Housing and cartridge were identified as the key components having a significant impact on a high leak defect rate. Furthermore, key characteristics of these components — the cartridge split line and the housing roundness — were characterised and tolerances were applied accordingly.

Resolving complex problems under the time constraint is a big challenge for any root-cause analysis team and methodology. 8D provides a structured problem resolution within a limited time but may fall short when dealing with complex systems and products. On the other hand, the Six Sigma methodology provides a comprehensive framework for a complex problem resolution. However, when quick management of complex problems is required, a combined approach, as shown during the research study, is recommended. The issue of high leak rejects was managed from the perspective of all stakeholders and cost to business was kept to a minimum while the permanent corrective action was found for the problem.

Overall, the combined approach of 8-Discipline and the Six Sigma methodology together with key industry-standard analytical tests, proved successful in resolving a complex issue in the bath and shower industry within time constraints. The current research study was conducted on a new product, but the tech-

nology was similar to that of previous products in terms of assembly, sealing of components etc. It will, therefore, be useful for future research to try this methodology on a new innovative product in the absence of historical product knowledge.

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Essential competencies for engineers from the perspective of fresh graduates

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ABSTRACT
Determining the competencies required for engineering programmes has become important due to the increasing challenges faced by engineers after graduation and the tremendous development in technology. This research aims to identify the general competencies that fresh graduate students of engineering schools in Jordan believe they need to become competent and effective in their profession as engineers. This study was the first of its kind with students as respondents, and it was the first study of this kind in Jordan. Competencies were collected from a previous study with 48 competencies split into 11 groups. A questionnaire was prepared with these competencies, then rated for the degree of importance by answering "What engineering competencies graduates will require for their future work in Jordan?" The study showed that all competencies were vital, including technical, personal, non-technical and attitudinal competencies. This study will help to link the outputs of university education provided by engineering departments with market needs as well as to harmonise study programmes offered by Jordanian universities. Also, the research outputs are expected to facilitate the transition process of students from one university to another. The empirically identified competencies could be used to help assess different engineering study programmes in Jordan.

KEY WORDS
engineering, Jordan, competencies, graduate, education

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Introduction

The importance of this research comes from the fact that in Jordan, most engineering graduates become construction project leaders, e.g. project managers. Project managers play a major role in the failure or success of the construction industry business, and one way to improve the effectiveness of the construction industry is to improve the competencies of graduates from engineering study programmes. This would definitely contribute to nation-wide cost savings. For Jor-

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dan to achieve advancement in the construction sector, competencies of these graduates must be determined and used so as to get the best result with fewer risks.

This study contributes to the worldwide picture of competencies required for engineers by complementing similar studies in Europe, Australia, and North America with a Jordanian viewpoint. The study is based on the perspective that an engineering programme evaluation should determine whether graduates have the competencies needed for their future work.

No similar study focusing on the competencies required by graduates of engineering study programmes has been previously conducted in Jordan. Also, it could not be assumed that results from other parts of the world could be generalised to Jordan. In general, this study provides results that could help to improve engineering education in Jordan.

The novelty of this research study comes from identifying generic engineering competencies that are perceived to be important by engineers across all disciplines, focusing on recent graduates. This study is the first of the kind conducted in Jordan and the Middle East. A relevant question for research and practice is, therefore, "What engineering competencies graduates will require for their future work in Jordan?"

Therefore, this study aimed to identify a concise list of competencies suitable for profiling the competencies of graduates from engineering study programmes then ranking these competencies according to the degree of importance.

1. Literature review

The word "competent" comes from the word "competentia" in Latin. This term is defined as: "to struggle against another", and "to go hand in hand with someone or something" (Dante et al., 2012). Hornby and Thomas (1989) defined competency as "the knowledge, skills and qualities needed by effective managers" and pointed to "the ability to effectively perform the functions associated with management in a workplace." Hogg (1993) explained that competencies were characteristics of a manager that guided the demonstration of skills and abilities that contributed to successful results within an occupational field. Kinkel et al. (2017) used the term competence to define the individual dispositional ability and readiness to act successfully and in a self-organised manner when facing novel, unstructured or complex situations or tasks and the ability to develop solutions for future situations.

Conceptual understanding and terminology related to generic competencies have varied, in particular at the higher education level (Solesvik, 2019; Mutiara et al., 2019; Šafránková & Šikýř, 2018). Billing (2003) researched standard graduate competencies required for jobs in various countries and found that skills can be exported to different countries. Barrie (2006) considered the definition of generic attributes for graduate students to be different within the same discipline and within the same institution. As in the US and Europe, several changes have occurred in Australia's engineering education in recent decades (Ferguson, 2006). Such changes have been generally determined by findings required for programme accreditation (Engineers Australia (EA) 2005a, 2005b, The Quality Assurance Agency (QAA) 2006, Accreditation Board for Engineering and Technology (ABET) 2008, European Network for Accreditation of Engineering Education (ENAEE) 2008). These require education to include non-technical content. The outcomes of the programmes specified by ABET, ENAEE and EA were similar, although they theoretically grouped outcomes differently. EA specified ten generic attributes, such as ABET's 11 programme outcomes. Nearly half of ABET and EA attributes were non-technical. Five of ENAEE's six systems, by comparison, were mostly academic. But non-technical items recorded independently by EA and ABET were included in the transferable skills of the ENAEE outcome (ENAEE, 2008). Apart from work that aimed to set accreditation criteria, other important studies focused on various stakeholders. Research across a broader range of industries included SPINE: Successful Strategies of Global Engineering Education Benchmarking Review (Bodmer et al., 2002) for ten universities in Europe and the United States, a study conducted at the Royal Academy of Engineering in the United Kingdom (Spinks et al., 2006), a research conducted at Iowa State University (Brumm et al., 2006) and a survey at the University of Illinois (Meier et al., 2006).

The SPINE research interviewed academic staff, engineers with five to ten years of experience and directors of human resources (Bodmer et al., 2002). Data from 444 firms were obtained by UK research (Spinks et al., 2006). Together, the SPINE and the UK research looked at broad-level issues and concentrated on knowledge and skills while specifically addressing behaviour. Attitudes were protected against by the theoretical framework for the UK report. Iowa and Illinois research, on the other hand, considered attitudinal skills important.

The Iowa research surveyed 212 participants, including clients, staff and graduates. In addition, 14 competencies were defined and extended to include 61 main actions. In the Illinois study, 415 institution managers ranked the importance of 54 skills.

According to Tucker and Cofsky (1994), competence may have five major components: experience refers to personal information, learning skills — to the person's ability to perform a specific task, self-concepts and values — to a person's behaviours, beliefs and self-image — to physical characteristics, and clear reactions — to circumstances or data and ultimately to emotional impulses or related patterns that function promptly. Katz and Kahn (1966) divided competence into four areas of expertise: technical/functional (such as knowledge, attitudes and skills), management (such as knowledge and skills), human (knowledge, attitudes and skills), conceptual (capacity to imagine the unseen and to think, and use intuition in the planning of future businesses). Kinkel et al. (2017) described four clusters of competencies, namely, network competence, creative problem-solving competence, overview competence and integration competence that are crucial for the innovativeness of the value creation champions involved in the ChampNet project.

Osagie et al. (2016) stated studies that investigated individual competencies for corporate social responsibility (CSR), which were often conceptual in nature, and oriented towards educational programmes. But in the study, the authors performed a theoretical and empirical analysis of the individual CSR-related competencies needed by CSR professionals to contribute to achieving effective CSR implementation in a corporate context. The literature review complemented with interview data resulted in the eight distinct CSR-related competencies.

Budiman et al. (2020) stated that the Graduates Competency Standards (GCS) from the Bachelor of Education Programme in Indonesia were formulated in graduate learning outcomes which included: understanding competencies, educative learning competencies, mastery competence in the scientific field and/or expertise, and the competency for attitude and personality.

A framework that describes the competencies required for a specific job or organisation to achieve success is considered a model of competency. Depending on the working environment and structure, a group of maximum seven to nine competencies are normally required for a particular job and as shown in the competency model (Schippmann et al., 2000). Several models have been developed around the world for several jobs and organisations (Cheetham et al., 1996; CIOB, 1996; McClelland, 1973; Boyatzis, 1982; Omran & Suleiman, 2017).

The Definition and Selection of Competencies (DeSeCo) is a project that provided a rich theoretical framework for conceptual understanding (OECD, 2002). The skills indicated by the DeSeCo project could only be observed in real actions of an individual under specific situations. External criteria, capabilities and environments are all part of the complex essence of competencies (OECD, 2002). The framework defines competencies revealed in action as best evaluated through performance observations (Rychen & Salganik, 2003). Consequently, the DeSeCo framework was consistent with frameworks assumed by other engineering study programme.

While large-scale studies on competencies required for engineers in the US and Europe were conducted, a large-scale study was necessary to verify whether the findings from the US and European research were applicable in Jordan.

2. Method

The design of this research was based on the study by Male et al. (2011). According to them, the DeSeCo framework was used for their study because its perspective was interdisciplinary, international and recognised the complexities of competencies (Male et al., 2011). From the DeSeCo framework, four complexities were particularly important to their research plan, namely, the following statements:

- Competencies are not independent but interrelated;
- A context is deemed relevant to the value of competencies;
- The stakeholder selection has an impact on competence selection;
- The outcomes of selected competencies affect the selection of competencies.

Without the existing literature, it would have been necessary to use a qualitative approach to discover and explain competencies that could be important. Instead and based on the above reasons, competencies were adopted from Male et al. (2011). The competencies have been developed into a list and validated as relevant using a questionnaire survey.

Therefore, this study mainly aims to identify competencies perceived as important by "fresh engineering graduates" to perform their work or tasks in the future. Besides competence ratings, the survey gathered personal data of respondents.

To ensure that each competence is most closely related to the variable it represented, the exploratory factor analysis was demonstrated on competency items. Any item with factor loadings lower than 0.4 was removed from the analysis. The extracted 11 factors clarified 50 per cent of the variance of the retained 49 competence items (Male et al., 2011). Conceptually, the factor was named after the items that represented it. The competencies were grouped into 11 groups, as shown in Table 1.

A pilot study was conducted to eliminate potential misunderstandings and contradictions from the questionnaire and enhance its format, statement structure and the overall content. Some terms have been updated based on the feedback, competency items have been improved to be clear and concise, and competencies have been refined to a list of 48 items.

This research was unique because it challenged fresh graduates to consider their specific job criteria instead of rating competencies important to a group of experienced engineers. While referring to expertise, this study asked fresh graduates to answer the question "How important is each of the following competencies to do the job well?" (1=unnecessary; 5=critical). The questionnaire was translated from English into Arabic, to help respondents to understand the questionnaire more clearly as some did not have a good command of English. It took the participants an average of fewer than five minutes to complete it. The survey was carried out face-to-face for the convenience of the respondent.

According to the Ministry of Higher Education & Scientific Research (2019), there are ten public and 17 private universities in Jordan, 12 located in the capital Amman, which offer an engineering degree. These 12 universities were involved in this research survey. In 2018, more than 10 000 fresh engineering graduates were registered in the Jordanian Engineers Association — the target group of this study.

Based on the following equations, the relative sample was calculated (Barlett et al., 2001):

$$No = (\mathrm{t}^2 * s^2)/(d^2) \quad (1)$$

Where t=the value of the chosen α level of 0.025 in each tai=1.96; d=acceptable margin of error for the mean being estimated=0.15; s=the estimate of a standard deviation in the population=1.25; N0=266. The correction shall be done using the following formula:

$$N = No/[1 + (\frac{No}{pop})] \quad (2)$$

Taking the population=10 000, No=266, so N becomes=259. A simple random sampling was adopted, which represented the engineering schools in Amman, Jordan. In total, 259 questionnaires were distributed, and 204 questionnaires were completed and returned by fresh engineering graduates yielding a response rate of 79 per cent. The Statistical Package for Social Sciences (SPSS) Version 18.0, and Microsoft Excel 2016 were used to analyse the data. To rank the competencies within each group, the relative importance index RII was used.

Tab. 1. Competency factors and their reflecting items

Competency factor	Competency items that reflect the competency factor
Communication	Written communication, verbal communication, English, graphical communication
Working in diverse teams	Teamwork, interdisciplinary skills, diversity skills
Self-management	Info-management, managing development, self-management, managing communication
Professionalism	Demeanour, concern for others, honesty, commitment, self-motivation, loyalty
Creativity/Problem-solving	Embracing change, creativity, sourcing info, problem-solving, systems, critical thinking
Management/Leadership	Coordinating, leading, supervising, risk-taking, managing, meeting skills, focus, workplace politics, decision-making
Engineering business	Cross-function familiarity, liability
Practical engineering	Reliability, manufacturability, maintainability, integrated design
Innovation	Marketing, entrepreneurship, networking
Contextual responsibilities	Sustainability, social context, safety, community
Applying technical theory	Research, theory, modelling, 3D skills

3. Results and discussion

3.1. Demographic results

In total, 204 valid completed questionnaires were collected. The majority (88%) of respondents were of the Jordanian nationality; all of them were aged between 21 - 30, and 18% were females. These results were expected as most students in the Jordanian universities are of the Jordanian nationality, and they spend four years in the engineering school after finishing a high school at the age of 17. Based on the results, the engineering education could be described as a male-dominated sector. So, the study results could be generalised to males as more than 82% of students in the engineering schools are males.

3.2. Ranking and RII for competencies

This section aims to rate the value of the competency elements by their degree of relevance. The RII is a simple but effective approach that has been widely used to determine attitudes to the factors being assessed. Respondents were asked to rate competencies on a 5-point Likert scale (1 for not important to 5 — very important). In Tables 2 through 12, the RII was estimated based on the survey response.

Communication group

The communication group has four competencies which are English language, written, graphical, and verbal communication. The RII was used to rank the degree of importance of these competencies according to respondents. The results are shown in Table 2. The results indicated that the most important competency in the communication group was the English language with 0.923 RII, followed by written and verbal communication with 0.892 and 0.881 RII indices, respectively. The lowest important communication competency is the graphical communication competency with 0.881 RII. As Table 2 demonstrates, all competencies in the communication group are very important to engineers, with English being on top of the list as expected. Male et al. (2011) found that communication was the most important competence required by engineers in Australia. Also, Meier et al. (2000) included five highly important competencies in the communication group. In the UK, Spinks et al. (2006) showed that communication skills were considered important by the largest proportion of each cohort population. The results were consistent with a previous study made in the US (Brumm et al., 2006), which included the communication competency in the proposed Iowa State University (ISU) workplace competencies.

Tab. 2. Ranking and RII for the communication group competency

Competencies	RII	Rank
English language	0.923	1
Written communication	0.892	2
Verbal communication	0.881	3
Graphical communication	0.812	4

Working in a diverse team

Working in a diverse team requires three competencies, namely, teamwork, interdisciplinary skills, and diversity skills. Table 3 shows the results of the survey in this respect, demonstrating that the most important competency for working in a diverse team is teamwork with 0.0.871 RII, followed by interdisciplinary skills with 0.783 RII. The least important competency in this group is the diversity skills competency with 0.77 RII. The results are consistent with previous studies conducted in Australia (Male et al., 2011) and in the US (Brumm et al., 2006), which included the team wok competency in the proposed Iowa State University (ISU) workplace competencies.

Tab. 3. Ranking and RII for working in a diverse team

Competencies	RII	Rank
Teamwork	0.871	1
Interdisciplinary skills	0.783	2
Diversity skills	0.770	3

Self-management group

The self-management group has four competencies, namely, self-management, info-management, managing development, and managing communications. The RII and the ranking of the self-management competencies are shown in Table 4. The results indicated that the most important competency in this group was the self-management competency with 0.875 RII, followed by info-management and managing development with 0.852 and 0.841 RII indices, respectively. The least important competency was managing communications with 0.812 RII. Same results were found in Australia by Male et al. (2011), who found that the self-management group was considered the third most important competence required for engineers.

Tab. 4. Ranking and RII for self-management group

Competencies	RII	Rank
Self-management	0.875	1
Info-management	0.852	2
Managing development	0.841	3
Managing communications	0.812	4

Professionalism group

The professionalism group has six competencies, namely, honesty, commitment, demeanour, self-motivation, loyalty and concern for others. The results are shown in Table 5. According to the results, the most important competency in the professionalism group was honesty with 0.931 RII, followed by commitment with 0.923 RII. The least important competencies in this group were loyalty and concern for others with 0.871 and 0.833 RII indices, respectively. High importance ratings for the professionalism competency group were consistent with a previous study conducted in the US (Brumm et al., 2006), which included the professional impact competency in the proposed Iowa State University (ISU) workplace competencies, and the study by Male et al. (2001) in Australia.

Tab. 5. Ranking and RII for professionalism group

Competencies	RII	Rank
Honesty	0.931	1
Commitment	0.923	2
Demeanour	0.888	3
Self-motivation	0.874	4
Loyalty	0.871	5
Concern for others	0.833	6

Creativity/Problem-solving group

The creativity/problem-solving group contains five competencies, namely, problem-solving, creativity, info-sourcing, critical thinking, and embracing change. The results are shown in Table 6. According to respondents, is the most important was problem-solving competency with 0.929 RII, followed by creativity and sourcing info with 0.854 and 0.799 RII indices, respectively. The least important communication competency was embracing change with 0.777 RII. Creativity/problem-solving group was found important for engineers in the US study by Mier et al. (2000) and the study in Australia by Male et al. (2011). Both studies included five competencies in this group. Moreover, in the SPINE study (2002), which covered all Europe, the study found problem-solving skill as the most important skill for professors, engineers, and managers.

Tab. 6. Ranking and RII for creativity/problem-solving group

Competencies	RII	Rank
Problem-solving	0.929	1
Creativity	0.854	2
Sourcing info	0.799	3
Critical thinking	0.778	4
Embracing change	0.777	5

Management/leadership group

The management/leadership group comprises nine competencies. The competencies and their ranking are shown in Table 7. The results demonstrate that focus was the most important competency in this group with 0.909 RII, followed by managing with 0.896 RII. Least important competencies were workplace politics and risk-taking with 0.809 and 0.664 RII indices, respectively. These results correspond with the findings of the Australian study by Male et al. (2011), which considered these competencies as important and required for engineers.

Tab. 7. Ranking and RII for management/leadership group

Competencies	RII	Rank
Focus	0.909	1
Managing	0.896	2
Decision-making	0.894	3
Leading	0.893	4
Supervising	0.884	5
Meeting skills	0.877	6
Coordinating	0.869	7
Workplace politics	0.809	8
Risk-taking	0.664	9

Engineering business group

The engineering business group contains only two competencies, namely, liability with 0.93 RII and cross-function familiarity with 0.824 RII. Results are shown in Table 8. The results are consistent with Male et al. (2011) and Nguyen et al. (1998), who found that engineering business practice is one of the most important competencies required by engineers in Australia. Also, the study by Brumm et al. (2006) included the customer focus competency in the Iowa State University (ISU) workplace competencies.

Tab. 8. Ranking and RII for engineering business group

Competencies	RII	Rank
Liability	0.930	1
Cross-function familiarity	0.824	2

Practical engineering group

The practical engineering group contains four competencies, including integrated design, reliability, manufacturability, and maintainability. The results are shown in Table 9. On the top of the list is the integrated design competency with 0.892 RII, followed by reliability, manufacturability and maintainability with indices of 0.879, 0.833 and 0.814, respectively. Nguyen et al. (1998) found technical knowledge and skills as the most important generic skills and attributes for academics, the industry, and students. Also, the results were consistent with a previous study conducted in the US (Brumm et al., 2006), which included the engineering and general knowledge competency in the Iowa State University workplace competencies. Furthermore, the SPINE study (2002) found practical engineering experience competency as one of the important skills for professors, engineers, and managers in Europe.

Tab. 9. Ranking and RII for the practical engineering group

Competencies	RII	Rank
Integrated design	0.892	1
Reliability	0.879	2
Manufacturability	0.833	3
Maintainability	0.814	4

Innovation group

The innovation group covers three competencies, namely, networking, entrepreneurship, and marketing. The results are shown in Table 10. The results revealed that networking competency had the highest RII 0.879, followed by entrepreneurship and marketing with 0.841 and 0.734 RII indices, respectively. The results were consistent with findings on an earlier study conducted in Australia (Male et al., 2011), the study by Spinks et al. (2006) in the UK, and a study made in the US (Brumm et al., 2006), which included the innovation competency in the Iowa State University (ISU) workplace competencies.

Tab. 10. Ranking and RII for the innovation group

Competencies	RII	Rank
Networking	0.879	1
Entrepreneurship	0.841	2
Marketing	0.734	3

Contextual responsibilities group

This group has four competencies, namely, safety, sustainability, community and social context. The results provided in Table 11 demonstrate that safety sustainability competencies have 0.927 and 0.863 RII indices, but the community and social context competencies have almost the same RII 0.793. These results are consistent with findings of the study conducted in the US (Brumm et al., 2006), which included the cultural adaptability competency in the proposed Iowa State University (ISU) workplace competencies. Also, the results are in line with findings by Male et al. (2011) and Nguyen et al. (1998), who found that contextual responsibility was one of the important competencies required by engineers in Australia.

Tab. 11. Ranking and RII for contextual responsibilities group

Competencies	RII	Rank
Safety	0.927	1
Sustainability	0.863	2
Community	0.793	3
Social context	0.792	4

Applying technical theory group

The applying technical theory group comprises four competencies. The competencies and their ranking are shown in Table 12. The results demonstrate that research competency is the most important one in this group with 0.827 RII, followed by 3D skills with 0.766 RII. The least important competency is theory with 0.676 RII. These results are in the same line with findings by Male et al. (2011) and Nguyen et al. (1998), who considered technical knowledge as the most important generic attribute required for engineers in Australia by academics, the industry, and students. Also, the results are consistent with a previous study conducted in the US (Brumm et al., 2006), which

Tab. 12. Ranking and RII for applying technical theory group

Competencies	RII	Rank
Research	0.827	1
3D skills	0.766	2
Modelling	0.679	3
Theory	0.676	4

included the general knowledge competency in the Iowa State University (ISU) workplace competencies.

4. Ranking and RII for competency groups

Once the RII indices are found, and the ranking of competencies in each group is completed, the next step is to organise eleven groups according to the RII. This was done by averaging the RII indices of the competencies in each group. Results are shown in Table 13 and Fig. 1. According to the results, ten competency groups have over 0.8 RII, which indicates that fresh engineering graduates rated these competencies as very important for their future career. This result is in line with findings by Male et al. 2011, who found that ten out of 11 groups had a factor of importance rating above three (with 1 for not needed and 5 — critically needed).

Tab. 13. Ranking and RII of competency groups expected to be required for fresh engineering graduates

Name of group	RII	Rank
Professionalism	0.886	1
Engineering business	0.877	2
Communication	0.877	3
Management/leadership	0.855	4
Practical engineering	0.854	5
Self-management	0.845	6
Contextual responsibilities	0.843	7
Creativity/problem-solving	0.827	8
Innovation	0.818	9
Working in diverse teams	0.808	10
Applying technical theory	0.737	11

The high rating for professionalism (RII=0.886), which is attitudinal, is consistent with findings of earlier studies conducted in the US and Australia. This study broadly confirmed the results of the studies made in Australia. This group of competencies includes honesty, commitment, demeanour, self-motivation, loyalty, and concern for others.

On the other hand, the least important competency group is applying technical theory with 0.737 RII. This result is exactly in line with findings by Male et al. (2011) who concluded that relatively low ratings of importance for the most technical items were consistent with studies concentrating on the competencies required for engineering work. In their survey, Spinks et al. (2006) found that employers considered theoretical understanding to be relatively low as a skill that their graduates needed over the next ten years.

In spite of the moderately low ratings of technical competencies, they were amongst the competencies identified as generic for fresh engineering graduates. Male et al. (2011) promoted the prominence of technical competencies in the accreditation criteria that protect the society from potentially incompetent graduates of engineering study programmes.

To sum up, the identified technical and non-technical competencies include similar attitudes to those demonstrated by earlier studies conducted in the United States and Europe. As technical competencies,

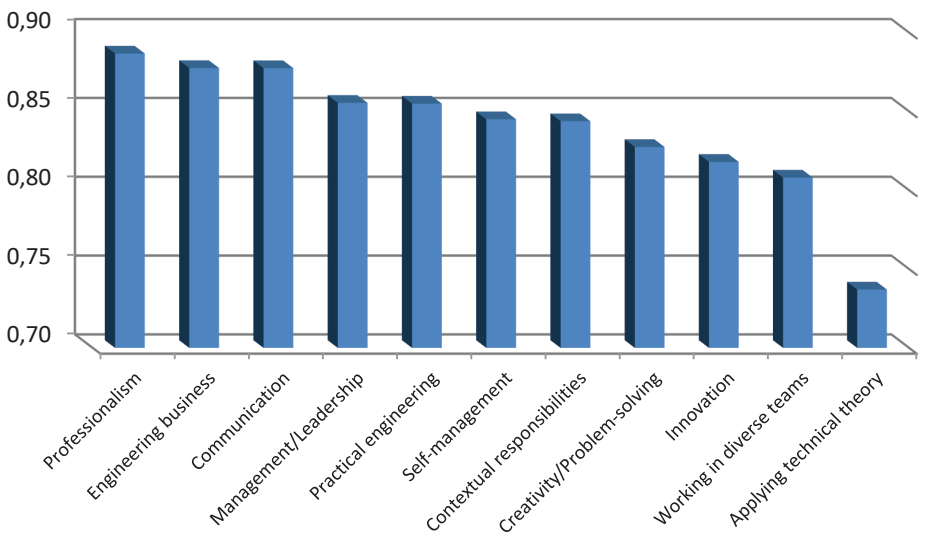

Fig. 1. Ranking and RII for competency groups expected to be required for fresh engineering graduates

non-technical competencies and attitudes were deemed relevant.

Conclusions

As discussed previously, a major driver of the current accreditation requirements is to broaden the programme beyond the academic emphasis, including communication collaboration, ethics, social and environmental concerns. The results of this study support such development.

The eleven empirically defined competency factors are ideal to be used as part of the assessment and development of Jordanian engineering study programmes. Proof that graduates possess these competence factors will imply that the competencies required for engineering work are being established in the engineering education system.

The engineering competencies in the Jordanian engineering education sector could be summarised into two groups (non-technical and attitudinal). These competencies must be developed as well as others, identified in this research. Many educators recognise that development requires teaching and evaluation methods outside conventional seminars, tutorials, and laboratory sessions (Cameron, 2009). In terms of teaching settings, problem- or project-based learning provides opportunities to develop all groups of competencies, particularly interdisciplinary competencies (Kolmos, 1996). Cultural change is also necessary to raise the low status of technical competencies among engineering academics (Florman, 1997).

Training in engineering skills can be supplemented with business teaching in engineering. Also, cooperation between engineers and business academics must be explored. Furthermore, these efforts have the potential to ensure the international mobility of graduates from engineering study programmes, especially in the Middle East.

This study empirically identified the following 11 competency groups required for fresh engineering graduates, namely, professionalism, engineering business, communication, management/leadership, practical engineering, self-management, contextual responsibilities, creativity/problem-solving, innovation, working in diverse teams, applying technical theory. Non-technical and attitudinal competencies were assessed as important by engineers, which was consistent with earlier studies conducted in Europe and the US. This result supports the developments aiming to improve engineering curricula beyond technical skills in programme accreditation in Jordan and globally.

According to the results of this study, teamwork, management, communication, personal/attitudinal skills, problem-solving and the ability to learn were rated as highly significant. The competencies were established as essential by this research as well as verified by earlier studies.

More studies with other populations of engineers across Jordan and not only Amman would be useful to test the generalisability of results.

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Sustainable behaviour: evidence from Lithuania

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ABSTRACT
There is an increasing focus on bridging human behaviour and attitudes towards sustainability. This article focuses on the factors that influence sustainable behaviour of working people. Based on a systematic and comparative analysis of scientific literature, the authors of the paper present the theoretical conceptual model, which illustrates sustainable behaviour. The aim of the empirical research is to examine how employees relate to sustainable behaviour across generations, genders and different modes of education through economic, environmental and social domains. A quantitative method in the form of a survey was selected to capture individual employee attitudes and actions regarding sustainable behaviour. A total of 412 complete responses from Lithuanian employees were used for data analysis. The results of empirical research revealed a significant relationship between gender, generation and education, and sustainable employee behaviour.

KEY WORDS
sustainability, employee-related factors, sustainable behaviour

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Introduction

Humanity is facing increasingly complex environmental and sustainability challenges (Wamsler et al., 2018). We currently live in a world of constrained resources, growing populations and exceeding planetary boundaries (Evans et al., 2017). During the past years, there has been a growing pressure to be more concerned with the environmental and resource consequences of the products, services and processes, and the relationship between the profit, people, and

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the planet (Kleindorfer et al., 2005; Ciarniene et al., 2018; Perkumienė et al., 2019). The three-pillar approach of sustainability covering an ecological, socio-cultural and economic pillars was agreed upon during the Johannesburg Summit in 2002 (Horlings, 2015). The challenge is to integrate the issues of sustainability with products, services, processes, work systems, and existing frameworks of employee behaviour both at home and at the workplace (Kleindorfer et al., 2005; Blake-Beard et al., 2010; Gimenez et al., 2012; Zink, 2014; De Medeiros et al., 2018; Pabian, 2019). Employees with different values and demographic profiles, e.g., generation, gender, education etc., have individual priorities, expectations, and perceive their environment differently (Horlings, 2015; Stirpe & Zárraga-Oberty, 2017; Ciarniene et al., 2018). If so, they are likely to evaluate and respond to sustainable behaviour differently. A growing interest in sustainability and sustainable behaviour has been expressed in several research works that have examined various sustainability issues and contributed to the understanding of the outcomes for individuals, organisations and society. Although the scientific community has widely analysed the topic of sustainable behaviour during the past years, combinations of various employee-related factors affecting sustainable behaviour constitute a research gap to be further observed.

The purpose of this paper is to examine the influence of related factors on sustainable behaviour of working people. Therefore, the paper is organised as follows. The next section provides an analysis of the scientific literature on the dimensions of sustainability, the main characteristics of sustainable behaviour, and factors affecting the sustainable behaviour of employees. Section 3 presents research methods, and Section 4 examines how working people of Lithuania relate to sustainable behaviour across generations, genders and different modes of education. The final section of this paper provides a discussion, limitations and directions for future research works.

1. Literature review

1.1. The dimensions of sustainability

Sustainable development is a major challenge facing people, organisations and societies today. According to Kleindorfer et al. (2005), Gimenez et al. (2012), Martens & Carvalho (2017), Ciarniene et al. (2018), and Spijkers (2018), sustainability integrates social, environmental, and economic responsibility to create a rational use of present resources, protect the welfare and well-being of every generation, and to offer a healthy and decent human environment for future generations. Environmental, social, and economic challenges have become increasingly complex, forcing people, organisations and societies to innovate, manage change, and adopt new technologies, new activities, new work arrangements, personal attitudes and behaviours (Horlings, 2015; Young et al., 2015; Martens & Carvalho, 2017; Kim & Park, 2017; Ciarniene et al., 2018; De Medeiros et al., 2018; Ahmed et al., 2019; Vveinhardt et al., 2019). Environmental sustainability is related to environmental integrity and protection, pollution control, the availability of natural resources and the protection of species and their ecosystems. Social sustainability makes sense of various concerns regarding the impact of products or operations on human rights, labour, health, safety, the well-being of organisational employees, regional development, and other community issues. The economic dimension refers to business sustainability and its human resources engaged in sustainable wealth creation processes, cost savings, operational efficiency, and financial performance (Katsoulakos &, Katsoulacos, 2007; Blake-Beard et al., 2010; Horlings, 2015; Kim & Park, 2017; Ciarniene et al., 2018).

Sustainability consists of a process of change through the dissemination of innovations, system innovations, sustainable innovations, transformations in existing production and consumption systems; consequently, it requires activities, mental models, and behaviours (Lozano, 2015; Evans et al., 2017; De Medeiros et al., 2018; Kułyk et al., 2017). The transformation to sustainability in the company, society and in the world is not only driven by practices and political structures, but also by beliefs, values, worldviews and paradigms that influence attitudes and actions (Horlings, 2015), and it begins with individual change. One cannot do for a community what one cannot do for one's self (Pappas & Pappas, 2015). Insight in this "inner" dimension of sustainability helps us to understand the influence of ethical choices on daily activities and provides an insight into why people would accommodate change (Horlings, 2015).

1.2. Main characteristics of sustainable behavior

According to Pappas & Pappas (2015), greater sustainability results from aligning our day-to-day behaviours with our well-stated values. Knowledge, values, and behaviours seem to be at the centre stage in the question of how to achieve transformations towards sustainability (Alroe et al., 2017). Sustainable behaviour has become an expression that is commonly used and is often substituted with other popular and trendy expressions, such as pro-ecological, environmentally friendly, eco-friendly, green behaviour, sustainable consumption behaviour, sustainable living, and sustainable cohabitation (Young et al., 2015; Sharma & Jha, 2017; Huba, 2006; Minton et al., 2012; Poškus, 2016; Bulut et al., 2017; Kułyk et al., 2017; Diprose et al., 2019). Research on sustainable behaviour can be executed differently (Poškus, 2016). Some researchers focus on the cognitive and moral aspects of sustainable behaviour (Chan & Bishop, 2013; Greaves et al., 2013). Other researches emphasise the role of personal values (Horlings, 2015; Jakovcevic & Steg, 2013), while the third apply hands-on and experimental approaches (Bohner & Schlüter, 2014) or place-based approaches (Messely, 2014; Horlings, 2015).

Describing sustainable behaviour Tapia-Fonllem et al. (2013) proposed to include pro-ecological, frugal, altruistic and equitable actions as instances of sustainable behaviour (Fig. 1). Pro-ecological behaviour is related to purposeful and effective actions that result in the conservation of natural resources. Recycling, composting, solid refuse control, water conservation, energy-saving behaviours, reading about environmental topics, and pro-ecological persuasion of others can be good examples of pro-ecological behaviours (Corral-Verdugo et al., 2010; Tapia-Fonllem et al., 2013). According to Tapia-Fonllem et al. (2013), frugality refers to a decreased level of consumption. It is an antagonist to consumerism and a fundamental behavioural characteristic of a sustainable lifestyle. Altruism can be defined as a motivational state aimed at increasing the well-being and benefits of others, the willingness to do things that bring advantages to others, with little or null interest in gains for oneself (Batson, 1991; Tapia-Fonllem et al., 2013). Equitable behaviour is related to sharing the satisfaction of needs between the present and future generations, the balance between human well-being and the integrity of ecosystems (Tapia-Fonllem et al., 2013).

Corral-Verdugo et al. (2010) produced a psychological measure of equitable behaviour, which included the assessment of social, racial, economic, age, and gender equity.

1.3. Factors affecting the sustainable behaviour of employees

Horlings (2015) emphasised the value concept in understanding sustainable behaviour. Values are the essential foundation of society and the rules that define human interactions. Individual values can be changed by education, information communicated through the media, community or other social pressure, a scientific understanding, the example of a charismatic person, or a process of religious adoption or conversion. A combination of these change mechanisms is even more effective in modifying values (Dahl, 2019).

Research shows that priorities, expectations, and behaviours of employees are related to their values and demographic profiles, i.e., generation, gender,

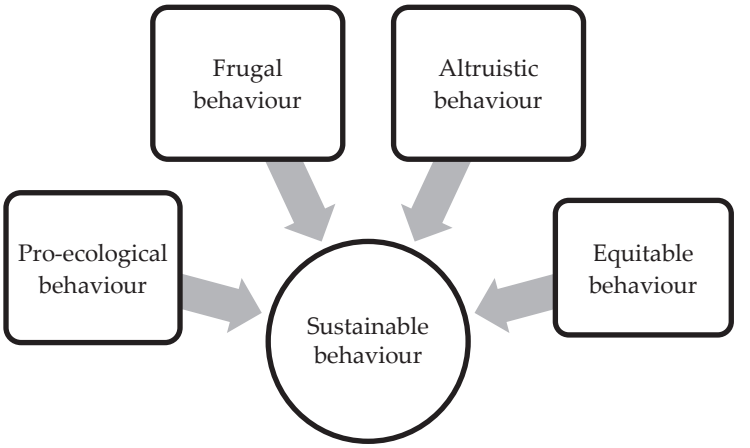

Fig. 1. Characteristics of sustainable behaviour
Source: elaborated by the authors based on (Tapia-Fonllem et al., 2013).

and education (Stirpe & Zárraga-Oberty, 2017; Ciarniene & Vienazindiene, 2018). The concept of a generation refers to an aggregate of people differentiated from others by their year of birth, age, location, and significant life events at critical developmental stages (Sun & Wang, 2010; Ciarniene & Vienazindiene, 2018). Employees now fall into four main generations: the Traditional Generation (born 1922 to 1943); the Baby Boom Generation (born 1944 to 1964); the Generation X (born 1965 to 1981); and the Generation Y or Millennials (born 1982 to 2002) (Abrams & Von Frank, 2014; Szydło, 2017).

Each generation is both a trustee of the planet with responsibilities to care for it and a beneficiary with rights to use it (Spijkers, 2018). But distinctive features of the generations likely provide some differences towards sustainability. Research of Diprose et al. (2019) disclosed a predominant generational narrative of frugality versus excess, with younger generations often negatively stereotyped as increasingly consumer-driven and environmentally destructive. Data showed that younger generations are more environmentally conscious and more likely to think about the environmental aspects of sustainable consumption. The research of Bulut et al. (2017) also showed that generation is associated with unneeded consumption as a dimension of sustainable consumption behaviour. According to this research, Baby Boomers were found to have the highest level of unneeded consumption behaviour while representatives of Generation Z — the lowest. According to Fleith De Medeiros et al. (2018), distinctive characteristics of generations cause some to have more sustainable actions (such as the Generation Z), while others tend to have more self-directed behaviour and a short-term vision (such as the Generation X). According to Coughlin (2018), a majority of Millennials believe that they are more concerned about protecting the environment than older generations. Meanwhile, a majority of older people representing Generation X and Baby Boomers saw themselves as more environmentally minded than when they were in their twenties. The older generations also performed a significant portion of volunteer work in the area of different environmental actions.

Gender role theory explains that men and women invoke different personal identities for their work–family demands (Ciarniene & Vienazindiene, 2018; Szydło, 2016). Although both men and women care about sustainability, their attitudes and practices towards sustainable behaviour can be different. The data of the study conducted by Khan and Trivedi (2015) confirmed that gender differences existed when it came to efficient use of resources, green initiatives, and minimising wastage. According to this research, women are more focused on purchasing and consuming products that are environmentally friendly, more thoughtful of energy conservation and other natural resources compared to men. Authors also highlighted that sustainable consumption needed to be differentiated into household and business needs-based consumption. Research findings by Bulut et al. (2017) supported the association between gender and sustainable consumption behaviour. According to this research, women showed a higher level of sustainable consumption behaviour and a higher tendency to reuse products.

Research results of Hamid et al. (2014) showed that sustainable consumer behaviour had a significant relationship with education. Different modes of education play a fundamental role in sustainable behaviour.

Based on the systematic and comparative literature analysis presented above, authors present a theoretical conceptual model, which illustrates the sustainable behaviour of employees (Fig. 2).

The key to living more sustainably is mainly about the choices that individuals, organisation, states and societies make. Sustainable employee behaviour (pro-ecological, frugal, altruistic and equi-

Fig. 2. Theoretical conceptual model of the sustainable behaviour of employees

table actions) is influenced by employee-related factors and can be assessed through economic, environmental and social dimensions. Behaviour towards sustainability serves a triple purpose contributing to micro and macro levels, when meeting the needs of individuals, goals of an organisation and providing benefits to society as a whole.

2. Research methods

The empirical part focuses on employee-related factors and covers household activities of sustainable employee behaviour. This research aimed to examine how employees related to sustainable behaviour across generations, genders and different modes of education. To explore the research aim outlined above, a quantitative method was selected to capture individual employee attitudes and actions regarding sustainable behaviour.

The empirical research design consists of a survey developed by authors. The questionnaire was designed as a combination of two building blocks. The first block of questions was related to sociodemographic characteristics of respondents. The second block was devoted to disclosing of the manifestation of sustainable behaviour and the evaluation of these aspects in daily activities of employees:

- Economically sustainable behaviour domain consists of 13 statements (sources: Blake-Beard et al., 2010; Horlings, 2015; Ciarniene et al., 2018; De Medeiros et al., 2018; Kim & Park, 2017; Katsoulakos & Katsoulacos, 2007; Poškus, 2016; Bulut et al., 2017; Khan & Trivedi, 2015), that evaluate sustainable wealth creation, minimising wastage, cost savings and other economic issues.
- Environmentally sustainable behaviour domain measures environmental integrity, protection of natural resources, recycling, composting, and energy-saving and consists of 17 statements (sources: Zink, 2014; Young et al., 2015; Sharma & Jha, 2017; Huba, 2006; Minton et al., 2012; Hanson, 2013; Poškus, 2016; Bulut et al., 2017; Diprose et al., 2019; Messely, 2014; Tapia-Fonllem et al., 2013; Abrams & Von Frank, 2014; Kułyk et al., 2017).
- Social sustainable behaviour domain consists of eight statements (sources: Blake-Beard et al., 2010; Ciarniene et al., 2018; De Medeiros et al., 2018; Spijkers, 2018; Kim & Park, 2017; Poškus, 2016; Diprose et al., 2019; Coughlin, 2018), that evaluate pro-ecological learning and persuasion, human health and safety, reusing of products and other community concerns.

Some items are assigned to two or three domains. Each item is measured on a 5-point Likert scale (1=strongly disagree, 5=strongly agree). A higher score represents a more prevalent sustainable behaviour related to a particular aspect. Each domain score was calculated as a mean score for the scale.

After the initial pool of questionnaire items was created, the statements were reviewed by five qualified social science experts specialising in sustainable management and economics. The revision of the statements allowed making some corrections to be sure the statements were accurate, free of item construction problems, and grammatically correct. The reliability of the questionnaire was evaluated using its internal consistency of the questionnaire items estimating the Cronbach's alpha values. Cronbach's alpha values were as follows: the economically sustainable behaviour domain — 0.80; the environmentally sustainable behaviour domain — 0.85; and the socially sustainable behaviour domain — 0.69. Statistically significant strong correlations were found between every domain of sustainable behaviour. The strongest relationship was detected between economically and environmentally sustainable behaviour ($r=0.980$, $p<0.001$). Pearson's correlation coefficients for economically and socially sustainable behaviour were 0.770 ($p<0.001$), and $r=0.820$ ($p<0.001$) for environmentally and socially sustainable behaviour.

A sample size calculator was used to determine the sample size (https://www.surveysystem.com/sscalc.htm#one). Based on the estimated sample, 430 questionnaires were delivered, using convenience sampling. Using this technique, data were obtained in the easiest possible manner. Data collection was conducted online and by distributing printed questionnaires to respondents. 412 questionnaires were filled out completely and were acceptable for analysis. The details of sample size are presented in Table 1.

The biggest part of respondents represented business sector employees (55.8%) with more than 11 years of work experience (67.3% of all the respondents). Sociodemographic characteristics of respondents are presented in Table 2.

The research was carried out in April – July 2019 in the Republic of Lithuania. All statistical analyses were conducted with SPSS version 22 (descriptive, two-way ANOVA and repeated measures ANOVA).

Tab. 1. Population and sample size calculation

Population size thousand	Confidence level %	Confidence interval	Sample size
1388.9*	95	5	384

*The number of employees (1st quarter of 2019)

Tab. 2. Sociodemographic characteristics of respondents

Characteristics (n (%))	Generation (the year respondents were born)			Total
	Baby boom 1944-1964	Generation X 1965-1981	Generation Y/ millennials 1982-2002	
Sample	128 (31.1%)	124 (30,1%)	160 (38.8%)	412
Female	80 (62.5%)	76 (61.3%)	76 (47.5%)	232 (56.3%)
Male	48 (37.5%)	48 (38.7%)	84 (52.5%)	180 (43.7%)

3. Research results

Data were collected from 412 employees (232 women and 180 men) representing three dominating generations across the labour market, i.e., the Baby Boomers, Generation X, and Generation Y. The largest part of respondents had a University education (332).

Respondents of the Baby Boomer Generation gained the highest scores on economically sustainable behaviour domain compared to younger participants of Generation X, and Generation Y ($F(2.409)=4.175$, $p=0.016$, Table 3). A higher level of sustainability related to economic issues was more typical to female respondents compared to male ($F(1, 409)=10.559$, $p=0.001$, Table 3). The results revealed a significant effect of a generation and gender interaction on economically sustainable behaviour ($F(2.408)=4.350$, $p=0.014$). Sustainable behaviour related to the economic aspect was more prevalent for women of the Baby Boomer Generation (but not Generation X) compared to male respondents.

There was a significant main effect of education on economically sustainable behaviour. Surprisingly, sustainable behaviour related to economic issues was the most typical for subjects with the lowest education (i.e., secondary, $F(2, 409)=4.209$, $p=0.016$; Table 3). Also, there was a significant education and a generation interaction effect (and the greatest one, considering partial etas2). This particular sustainable behaviour was least prevalent among the eldest respondents (Baby Boomers) with a college education and Generation X respondents with university education ($F(4.395)=8.189$, $p<0.001$).

Scores of the environmentally sustainable behaviour domain were the highest for the Baby Boomer group of respondents ($F(2, 405)=7.432$, $p=0.001$, Table 4). Female respondents had more prevalent sustainable behaviour and attitudes related to environmental issues compared to male ($F(1, 406)=14.413$, $p<0.001$, Table 4). There was a significant effect of the interaction between a generation and gender on environmentally sustainable behaviour and attitudes related to it ($F(2.408)=14.413$, $p<0.001$). Sustainable behaviour related to environmental issues was the most prevalent among female respondents of the Baby Boomers and less prevalent among Generation Y compared to male respondents.

The score of the environmentally sustainable behaviour domain was the highest for the group of respondents with secondary education and the lowest for the ones with a college education ($F(2, 407)=3.551$, $p=0.030$, Table 4). A statistically significant effect of the interaction between education and the year of birth was observed for environmentally sustainable behaviour and attitudes ($F(4, 399)=8.128$, $p<0.001$, Table 4). The highest scores for this domain were detected for the eldest respondents (the Baby Boomers) with a university and secondary education. Meanwhile, the most prevalent sustainable behaviour related to environmental issues was observed among Generation X respondents with secondary education.

Scores of the socially sustainable behaviour domain were the highest for the Baby Boomer respondents and the lowest for Generation Y respondents ($F(2, 408)=4.145$, $p=0.017$, Table 5). The social aspect of sustainable behaviour was more important for female respondents compared to male

Tab. 3. Effects of generation, gender and education on economically sustainable behaviour

	Category	Mean (st.d.)	Generation			F, p	Partial eta ^{2}
			Baby boom[A]	Generation X[B]	Generation Y[C]		
Generation			3.84 (0.58)	3.67 (0.56)	3.68 (0.51)	F=4,175, p=0.016	0.020
	Post hoc comparisons		F=10,559, p=0.001			p=0.033 [a-b] p=0.041 [a-c] p=0.968 [b-c]	
Gender	Female	3.81 (0.57)	0.026				
	Male	3.63 (0.52)					
Generation x gender	Female		3.96 (0.49)	3.64 (0.65)	3.81 (0.51)	F=4,350, p=0.014	0.021
	Male		3.65 (0.66)	3.71 (0.38)	3.58 (0.49)		
	Post hoc comparisons		p=0.001	p=0.454	p=0.007		
Education	University education [d]	3.72 (0.54)				F=4,209, p=0.016	0.021
	College education [e]	3.63 (0.57)					
	Secondary education [f]	3.97 (0.53)					
	Post hoc comparisons					p=0.971 [d-e] p=0.019 [d-f] p=0.019 [e-f]	
Generation x education	University education [d]		3.93 (0.53)	3.57 (0.55)	3.65 (0.50)	F=8,189, p<0.001	0.077
	College education [e]		3.23 (0.43)	3.89 (0.54)	3.77 (0.49)		
	Secondary education [f]		4.00 (0.66)	4.19 (0.29)	3.86 (0.55)		
	Post hoc comparisons		p<0.001 [d-e] p=0.700 [d-f] p=0.001 [e-f]	p=0.013 [d-e] p=0.001 [d-f] p=0.171 [e-f]	p=0.528 [d-e] p=0.191 [d-f] p=0.673 [e-f]		

(F (1, 411)=49.480, p<0.001, Table 5) and the analysis confirmed gender-related differences in this sustainable behaviour domain was significant enough (respondent's gender may explain about 10.8% of the change in socially sustainable behaviour and scores of the attitudes domain). The mean differences were statistically significant across every gender category, but it was the most statistically significant for the eldest respondents (the Baby Boomers). Statistically significant but minor differences were found in socially sustainable behaviour with respect to the level of education (F (2, 409)=3.270, p=0.039, Table 5). The least prevalent sustainable behaviour (social aspect) was specific for respondents with a college education, and the most prevalent behaviour was specific for those with university and secondary education.

Results revealed a significant effect of the interaction between education and generation on socially sustainable behaviour and attitudes (F(4.403)=11.956, p<0.001). Sustainable behaviour related to social issues was the most prevalent among the Baby Boomer respondents with university education and for Generation X respondents with secondary education.

Sustainable behaviour related to economic issues (the scale mean 3.69±0.60) was a bit less prevalent compared to socially sustainable behaviour (the mean 3.74±0.58; p=0.047 for pairwise comparison) and environmentally sustainable behaviour (mean 3.72±0.58, p<0.001 for pairwise comparison; p=0.728 for pairwise comparison between scores of socially and environmentally sustainable behaviour domains) when evaluating the whole sample (repeated measures ANOVA's F(2.406)=11.411, p<0.001, partial eta2 0.053).

Tab. 4. Effects of generation, gender and education on environmentally sustainable behaviour

	Category	Mean (st.d.)	Generation			F, p	Partial eta ^{2}
			Baby boom[A]	Generation X[B]	Generation Y[C]		
Generation			3.88 (0.54)	3.72 (0.51)	3.64 (0.54)	F=7,432, p=0.001	0.035
	Post hoc comparisons		F=14,413, p<0.001			p=0.050 [a-b] p<0.001 [a-c] p=0.669 [b-c]	
Gender	Female	3.83 (0.55)	0.034				
	Male	3.63 (0.50)					
Generation x gender	Female		4.02 (0.46)	3.73 (0.59)	3,73 (0,57)	F=3,258, p=0.039	0.016
	Male		3.66 (0.60)	3.71 (0.37)	3,56 (0,50)		
	Post hoc comparisons		p<0.001	p=0.880	p=0.047		
Education	University education [d]	3.73 (0.54)				F=3,551, p=0.030	0.017
	College education [e]	3.63 (0.54)					
	Secondary education [f]	3.94 (0.55)					
	Post hoc comparisons					p=0.640 [d-e] p=0.084 [d-f] p=0.028 [e-f]	
Generation x education	University education [d]		3.98 (0.49)	3.65 (0.50)	3.60 (0.53)	F=8,128, p<0.001	0.075
	College education [e]		3.25 (0.37)	3.84 (0.53)	3.85 (0.47)		
	Secondary education [f]		3.94 (0.69)	4.21 (0.22)	3.84 (0.57)		
	Post hoc comparisons		p<0.001 [d-e] p=0.857 [d-f] p=0.002 [e-f]	p=0.146 [d-e] p=0.003 [d-f] p=0.083 [e-f]	p=0.171 [d-e] p=0.054 [d-f] p=0.934 [e-f]		

There was a statistically significant effect of a generation on evaluations of economically, environmentally and socially sustainable behaviour and attitudes (repeated measures ANOVA's F (4, 406)=5.747, p=0.001, partial eta2 0.027, Fig. 3). Economically sustainable behaviour was the least prevalent compared to environmental issues for the Baby Boomer respondents. Economically sustainable behaviour of Generation X respondents was rated as less prevalent compared to the sustainable behaviour related to social and environmental aspects. Generation Y respondents evaluated socially, environmentally and economically sustainable behaviour equally (pairwise comparisons p>0.05).

Comparing various sustainable behaviour aspects and the importance of the particular sustainability area, differences were larger for the female sample compared to the male sample (female sample: F(2.409)=26.525, p<0.001, partial eta2 0.115; male sample: F(2.409)=8.896, p<0.001, partial eta2 0.042). Females gained the highest scores on every sustainable behaviour domain compared to males (Fig. 4 and Tables 2 – 4). In the female sample, the most important and prevalent was socially sustainable behaviour (the mean score of the domain was 3.91; Fig. 4), and the least common was sustainable behaviour related to economic issues (the mean score of the domain was 3.74). The opposite results were for the male sample: they gained the lowest scores in the socially sustainable behaviour domain (the mean score was 3.53); meanwhile, the economically and environmentally sustainable behaviour and attitudes were more important for men (mean scores were 3.63 for both domains).

Participants with secondary school education (F(2.408)=1.107, p=0.332, partial eta2 0.005) and

Tab. 5. Effects of generation, gender and education on socially sustainable behaviour

	Category	Mean (st.d.)	Generation			F, p	Partial eta ^{2}
			Baby boom[A]	Generation X[B]	Generation Y[C]		
Generation			3.87 (0.61)	3.72 (0.51)	3.68 (0.56)	F=4,145, p=0.017	0.020
	Post hoc comparisons		F=49,480, p<0.001 0.108			p=0.147 [a-b] p=0.015 [a-c] p=1.000 [b-c]	
Gender	Female	3.91 (0.57)					
	Male	3.52 (0.52)					
Generation x gender	Female		4.11 (0.50)	3.82 (0.56)	3.78 (0.60)	F=5,752, p=0.003	0,028
	Male		3.47(0.58)	3.48 (0.43)	3.58 (0.52)		
	Post hoc comparisons		p<0.001	p=0.001	p=0.020		
Education	University education [d]	3.75 (0.58)				F=3,270 p=0.039	0.016
	College education [e]	3.56 (0.57)					
	Secondary education [f]	3.87 (0.58)					
	Post hoc comparisons					p=0.111 [d-e] p=0.649 [d-f] p=0.043 [e-f]	
Generation x education	University education [d]		4.00 (0.56)	3.65(0.53)	3.62 (0.56)	F=11,956, p<0.001	0,106
	College education [e]		3.16 (0.33)	3.65 (0.59)	4.13 (0.13)		
	Secondary education [f]		3.50 (0.67)	4.25 (0.00)	3.88 (0.58)		
	Post hoc comparisons		p<0.001 [d-e] p=0.011 [d-f] p=0.143 [e-f]	p=0.994 [d-e] p=0.003 [d-f] p=0.008 [e-f]	p=0.011 [d-e] p=0.051 [d-f] p=0.270 [e-f]		

college education (F(2.408)=0.889, p=0.412, partial eta2 0.004; Fig. 5) valued economically, socially and environmentally sustainable behaviour and posture similarly (differences of mean scores of domains were statistically insignificant). Social aspects of sustainable behaviour were the most prevalent (the mean score of the domain was 3.75), and economic aspects of sustainability were the least important for the participants with university education (the mean score of the domain was 3.67; F(2.408)=14.102, p<0.001, partial eta2 0.065).

The analysis into the daily examples of sustainable behaviour by respondents in the whole sample determined that the highest percentage of assent was expressed in the following statements: I follow the opinion that it is not too late to learn and improve (95.10%); I care about my health and those around me (94.20%); I participate in deposit return schemes (92.20%); I sort rubbish (plastic, glass...) (81.50%); I don't smoke (80.60%); I hand over suitable items (clothes, shoes, books, furniture ...) for secondary utilisation (77.70%); I use electricity sparingly without leaving the electrical appliances unnecessarily (75.80%); I use water sparingly (68.90%); I use a reusable bag for shopping (65.10%); My purchases are premeditated, I don't buy what I don't need (62.10%); I don't throw away food (60.20%).

The lowest percentage of assent was identified to the following statements: I travel to and from work by public transport, by bike or on foot (34%); I use only environmentally friendly household products (cleaners, detergents ...) (34%); I participate in environmental management campaigns and activities (39.80%).

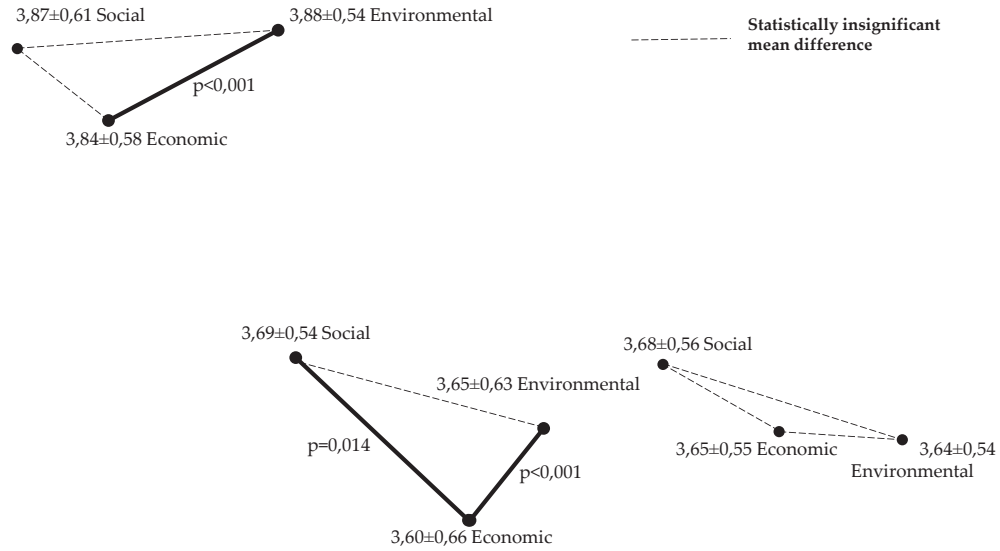

Fig. 3. Sustainable behaviour from the perspective of a generation

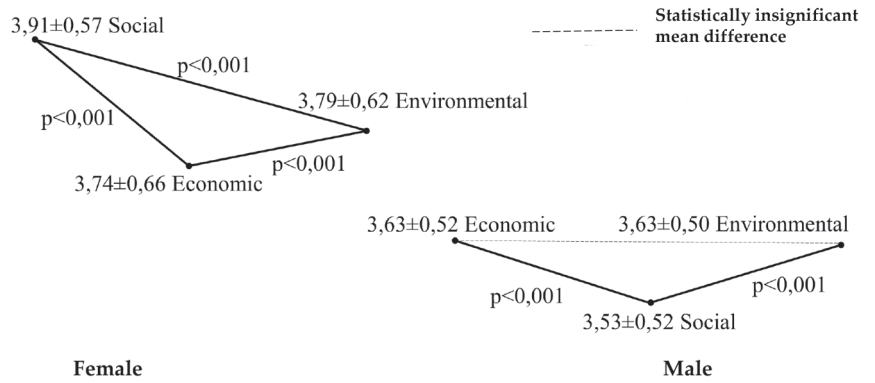

Fig. 4. Sustainable behaviour from the perspective of a gender

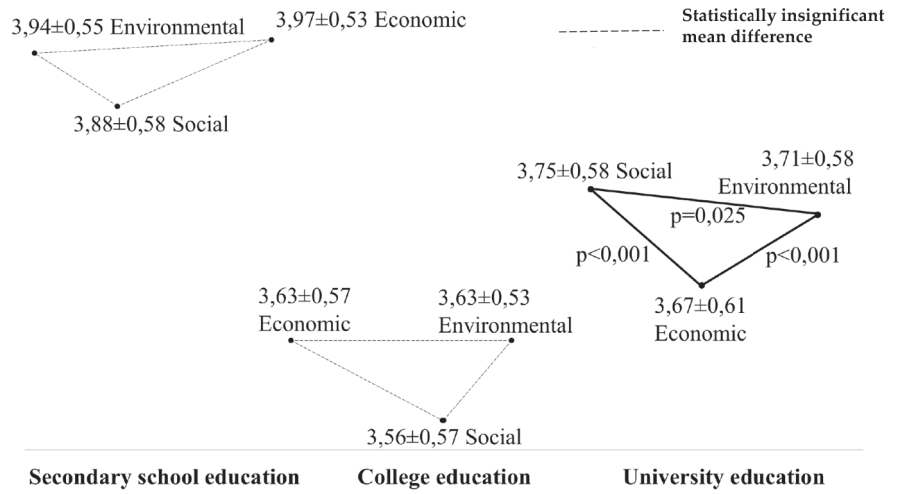

Fig. 5. Sustainable behaviour from the perspective of education

4. Discussion and conclusions

The topic of sustainable development is widely analysed by the scientific community. A combination of various employee-related factors affecting sustainable behaviour constitutes a research gap to be observed. As a theoretical contribution, this study showed that sustainable employee behaviour was influenced by a collection of interrelated external (organisation, state and society) and internal (values, attitudes, education, generation and gender) factors. The empirical research of this article examined the manifestation of sustainable behaviour and the extent to which internal individual factors affected sustainable employee behaviour through economic, environmental and social domains.

It should be remarked that the results of the empirical research fit the theoretical background in this particular field. Khan and Trivedi (2015) and Bulut et al. (2017) argued that gender differences existed in green initiatives, minimising wastage, consumption behaviour and higher tendency to reuse products. The data of this study confirmed that gender differences existed when it came to sustainable behaviour. The results of empirical research were similar to the above-mentioned studies and also indicated that a higher level of sustainability related to economic, environmental and social issues was more typical for female respondents compared to male.

Research works by Diprose et al. (2019), Bulut et al. (2017), De Medeiros et al. (2018), Coughlin (2018) disclosed generational differences in sustainable consumption behaviour and actions. According to the results of these efforts, younger generations were more environmentally conscious and behaved more sustainably. This current research proved that there was a statistically significant generational effect on evaluations for economically, environmentally and socially sustainable behaviour and attitudes. But on the contrary to the above-mentioned results, in terms of generations, the Baby Boomer respondents gained the highest scores on all three sustainable behaviour domains compared to younger employees.

Hamid et al. (2014) identified that sustainable consumer behaviour had a significant relationship with education. This current research revealed that there was a significant effect of education on economically and environmentally sustainable behaviour and attitudes. Sustainable behaviour related to economic issues was most typical for respondents with the lowest education. Minor differences were identified in socially sustainable behaviour with respect to the level of education.

Sustainable behaviour related to economic issues was a little less prevalent compared to socially sustainable behaviour and environmentally sustainable behaviour when evaluating the whole sample. Summarising the analysis of daily examples of sustainable behaviour in the whole sample, the highest percentage of assent was determined in the following fields: continuous learning, care about health; participation in deposit return schemes; rubbish sorting; tendency to reuse products; and sparing use of different resources.

The limitation of this paper is that convenience sampling was used for this research and data gathering was not optimal. The sample size of some subgroups was not big enough to represent the entire population of working people; therefore, the authors express concerns about widely applicable generalisations. Another limitation of this research was that it explored only the sustainable behaviour of employees without an analysis of other population groups. It is the first stage of research on sustainable employee behaviour. It focused only on internal factors and covered only household activities of working people. Concerning further research, it would be worth exploring how employees behave in organisations and how organisations support and encourage their sustainable behaviour.

The current research study opened some space for scientific debate and future contributions. The findings on sustainable behaviour can be useful for organisation leaders, practitioners, and policy-makers, as they call for consistent contributions on micro and macro levels, meeting the needs of individuals, organisations and the whole society. It could be significant for international readers and scientists working in the area of sustainable behaviour when conducting comparative analyses of sustainable behaviour across different countries. It would allow revealing some similarities and specifics among different countries and cultures.

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