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CONTENTS

BASIC INCOME: OPPORTUNITY OR PROBLEM?

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ABSTRACT

There has been an increase in debate over universal basic income in recent years, mostly related to the different welfare measures introduced in relation to the COVID-19 pandemic around the world, and because of the increasing relevance of labor market automation. In this study, our objective is to evaluate the attitudes of Hungarian citizens towards basic income, with a focus on its feasibility, as well as positive and negative effects. In order to accomplish this, we analyzed relevant international literature to draw up a questionnaire from studies, while also looking at background variables that potentially influence an individual's attitude towards basic income. Results show that Hungarian citizens rather disagree about the feasibility of a basic income scheme in Hungary but they are a lot more agreeable with the EU-s capability to provide one (18.4% compared to 52%, respectively. Regarding its possible positive impacts, the most frequently mentioned items include reducing anxiety about financing basic needs, helping people return to education, and offsetting the effects of automation, while concerns about the idea of not being researched and tested enough, its effects on inflation, and its possible work-discouraging nature were listed as the most relevant negative effects.
Keywords: basic income, Universal Basic Income, welfare attitudes, social protection, public opinion

INTRODUCTION

According to *Van Parijs* (2001), basic income is an income paid by a political community to all its members on an individual basis, without means test or work requirement. The idea has been receiving a lot of attention and traction recently, but the Universal Basic Income – and unconditional cash transfers – are not a new phenomenon. Thomas More and Johannes Ludovicus Vives wrote about providing a minimum standard of living as early as the early 1500s. More argued for this idea based on the reduction it would have on subsistence theft. On the other hand, Vives argued that providing a minimal level of livelihood is a "morally required charity" (*Van Parijs* 2021; *Van Parijs* 2004; *Van Parijs &Vanderborght*, 2017). In 1796, Thomas Paine proposed the introduction of a one-time benefit for all at the beginning of adulthood – a citizen's dividend – financed by a land value tax. His contemporary, Thomas Spence, advocated an even wider distribution of land value taxes in a form

which envisaged a full distribution of the land value tax left after public expenditure had been financed. In his 1796 book, The Rights of Infants (*Spence*, 1797) he wrote that the remaining money from land value tax – after financing public expenditure – should be given to *"all the living souls in the parish, whether male or female; married or single; legitimate or illegitimate; from a day old to the extremest age; making no distinction between the families of rich farmers and merchants and the families of poor labourers and mechanics"* (*Spence*, 1982, p. 84; *Van Parijs* 2021; *Van Parijs & Vanderborght*, 2017).

In 1962, Milton Friedman introduced a measure similar to the Universal Basic Income. In his 1962 work, Capitalism and Freedom (*Friedman & Friedman*, 1962) he coined negative income tax as a method of redistribution, a measure in which people earning under a certain level would not pay taxes, instead, would get a payout, financed by those who earn under certain level (*Van Parijs & Vanderborght*, 2017; *Van Parijs*, 2021). During this period, in the 60s and 70s, a large number of Universal Basic Income Trials took place in North America, including New Jersey, Pennsylvania, Seattle, Denver, and Manitoba, in Canada, which even to date, it is one of the best documented trials.

In this study, the objective of the authors is to evaluate the attitudes of Hungarian citizens to universal basic income with regards to its feasibility, general support, its possible effects on poverty, employment, education and many others by means of a questionnaire drawn up from relevant international surveys of the topic, following a systematic literature review aiming to point out the different variables that influence attitudes to basic income.

The research questions formulated to address attitudes were the following:

- To what extent does the population support the introduction of a basic income in Hungary and in the European Union?
- What is the opinion on the feasibility of a basic income, and its positive and negative effects?
- Which factors have a significant influence on attitudes towards basic income?

There are multiple reasons for the increasing attention to Universal Basic Income, but the two most prominent and obvious ones may be the COVID-19 pandemic, and the increasing importance of workplace automation – to which Universal Basic Income was connected to, as a possible measure to offset its enormous impact on the labor market, and with it, on people's livelihood. (*Manyika et al.* 2017; *Dermont & Weisstanner*, 2020; *Cseh & Varga*, 2020; *Kőmüves & Szabó*, 2021).

MATERIALS AND METHODS

First of all, the available international literature on the topic was evaluated in order to construct a survey that would be sufficient to assess the attitudes of Hungarian citizens regarding Universal Basic Income. The first step of this was conducting a systematic literature review, as stated earlier. These were supplemented by surveys on basic income available on the internet and grey literature.

Within the framework of our primary research, a survey was conducted among Hungarian citizens (n=125), which is not representative. In this research the authors

did not target specific age groups or specific occupational categories as the objective was to reach as a wide variety of people as possible.

To evaluate the data of the survey, descriptive statistical methods were used and the Cross-Tabulation Analysis examined the relations of background variables and different answers, during which we also considered Cramér's V to evaluate the strength of their relation. To measure the statistical significance of different variables, Pearson's Chi square (χ2) test was carried out. The statistical analysis was performed with SPSS statistical software. We considered statistical results to be significant at $p < 0.05$. To evaluate one to five Likert scales and background variables, one-way analysis of variance was used.

The composition of the sample used

The target group of the research was the Hungarian population without any targeting towards age, employment, or any other background. The demographic variety of the sample used can be seen in *Table 1*.

RESULTS AND DISCUSSION

In the first chapter of the questionnaire, our objective was to evaluate the knowledge and general attitudes of citizens to the Universal Basic Income. The first screening question was a simple yes/ no one if they have ever heard about the Universal Basic Income. 80% of people taking part in the questionnaire have heard about it before, and only 20% have not. We did not disregard the answers of those who had not heard about it before, since at the beginning of the survey, Universal Basic Income was described by 2 different interpretations, which is usual in surveys like this. The two descriptions were that of *Van Parijs* (2004) and the *ESS Round 8: European Social Survey* (2020) as shown below.

"A basic income is an income paid by a political community to all its members on an individual basis, without means test or work requirement" (*Van Parijs*, 2004, p. 2)

"The government pays everyone a monthly income to cover essential living costs.
- It replaces many other social benefits.
- The purpose is to guarantee everyone a minimum standard of living.
- Everyone receives the same amount regardless of whether or not they are working.
- "People also keep the money they earn from work or other sources." (*ESS Round 8: European Social Survey*, 2020, p. 48)

The last part of the definition from the European Social Survey also included a statement that Universal Basic Income is paid for by taxes. We have left this part out intentionally, since later on during the survey, we ask participants about the possible ways to finance a basic income scheme and including this part would have been a cause for confusion.

Table 1: Demographic composition of the sample analyzed (n=125)

Category	Share, %
Gender	
Male	46.4
Female	53.6
Age	
23 and under	37.6
24-39	32
40-53	20
54-65	7.2
65+	3.2
Residence	
Capital city	17.6
City with county rights	42.4
Other City/town	14.4
Other settlement	25.6
Education	
Primary education	0.8
Vocational or technical school	6.4
Certificate of secondary education	48
Higher education	44.8
Current occupation	
Active blue-collar worker	10.4
Active white-collar worker	41.6
Entrepreneur	0.8
On maternity/paternity leave	2.4
Retired	4.8
In education	36.8
Homemaker? housewife?	0.8
Unemployed	0.8
Inactive	1.6
Political self-identification	
Left	23.2
Center	48
Right	28.8
Ever received unemployment benefit	
Yes	22.4
No	77.6
Perception of relative income situation	
We make a very good living, and we can save a lot savings	24
We make a living, but we can only make a little savings	55.2
Just enough to live on, but we can't save anything	20
Sometimes not even enough to live on	0.8
We have regular daily livelihood problems	-

Support for introduction

In the next part of the survey, questions were focused on the introduction and feasibility of a Universal Basic Income in Hungary and in the European Union. Support for European and Hungarian introduction is presented by *Table 2* and *Table 3*.

Table 2: Should the introduction of a Universal Basic Income take place within the European Union in the forthcoming decades? (n=125)

Category	Share, %
Entirely disagree	8.8
Rather disagree	12.8
Neutral	20.8
Rather agree	33.6
Entirely agree	24

Table 3: Should the introduction of a Universal Basic Income take place in Hungary (independently of the European Union), in the forthcoming decades? (n=125)

Category	Share, %
Entirely disagree	12.8
Rather disagree	13.6
Neutral	22.4
Rather agree	32
Entirely agree	19.2

Support did not vary much between the introduction of the Universal Basic Income in the EU and in Hungary, respectively. In general, support for EU introduction was 6.4 percentage points stronger (57.6 vs. 51.2).

Feasibility and perceived effects of a basic income

The fourth and the last chapter of the questionnaire was designed following relevant international survey on attitudes to the Universal Basic Income. The survey also included in the literature review part earlier was the one carried out *by Dalia Research* (2017), *Yonder Consulting* (2018), and *YouGov* (2020). This chapter focuses on the individual perception of the effects about the introduction of a universal basic income, in general, both with positive and negative examples and on a personal level, as well.

The first question presented had a more general approach without differentiating between positive and negative effects regarding wealth equality, poverty and the workforce. The question was aimed at evaluating to what extent respondents would agree with the statements about the Universal Basic Income. The results are illustrated by *Figure 1*.

Figure 1: General statements about basic income, 1-5 Likert scale (n=125)
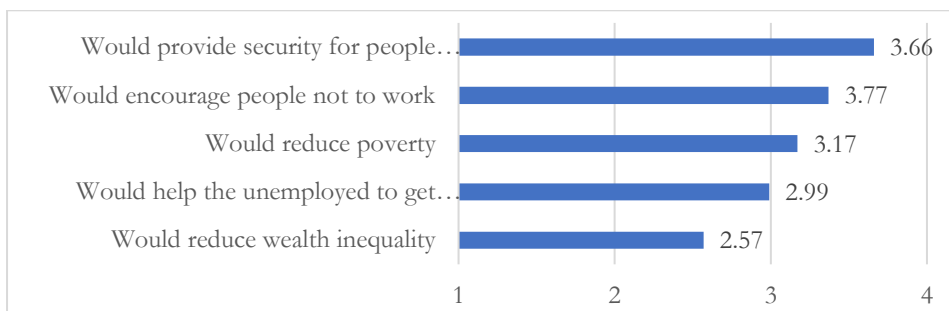
As stated earlier, universal basic income has been mentioned in connection with job losses due to widespread automation, and the COVID-19 pandemic, which makes these questions ever more relevant and also helps us to understand why this option has received the highest score. Coming out of a period with increased job insecurity with the shadow of another work-displacing phenomenon makes it hard to find a better reason for support than providing financial safety and security. The relatively high score of its discouraging work is not a surprise, either. The idea that a guaranteed cash transfer would make people choose not to work is the oldest and most frequently used argument against basic income. The questions of whether it would help the unemployed get back to the labor market and/or whether it would encourage people not to work can be argued from both sides. On the one hand, an unconditional payment could act as an incentive when compared to conditional ones like unemployment benefits – a payment that individuals lose when they return to work. In the Finnish Basic Income Experiment between 2017 and 2018, those who received a universal basic income started new jobs more frequently than those who were on unemployment benefits (the control group) (*Kangas et al.*, 2019). On the other hand, providing people with enough to live on might discourage people from working, especially in low-end jobs, which, after getting a sufficient amount of income, people would deem not good enough to do.

The next question in this chapter was about the perceived positive effects of the Universal Basic Income (*Figure 2*) based on surveys from *Dalia Research* (2017), *Yonder Consulting* (2018) and *YouGov* (2020).

In the *Dalia Research* (2017) survey mentioned above, the statement about reducing anxiety about financing basic needs was the most supported option. To compare the results of the survey of *Yonder Consulting* (2018) on the adult population of the United Kingdom where the authors used two questions, namely, whether a basic income would increase educational attainment, and it would reduce crime by eliminating destitution and extreme need, the following can be concluded. For the crime reducing extent of the basic income, results were really similar to the original one: 2.6 and 2.54, respectively . A statistically significant result can be found regarding an individual's political self-identification. Those on the political left have significantly been more agreeable to this statement than those on the right. *(SS= 26,.192; df=4; MS=6.548, F=4,.979; P=0.001)* To the issue of whether basic income would

increase educational attainment, the Hungarian participants gave a 2.82 score on the average while in the United Kingdom, it was 2.34.

Figure 2: The positive impacts related to a universal basic income (n=125)
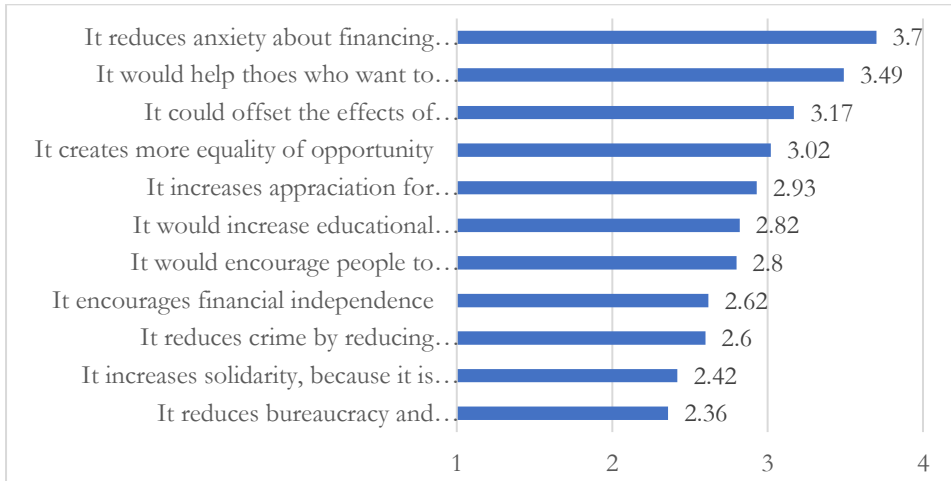
A significant difference between genders can be observed regarding the promotion of financial independence. While the average score for this option was 2.6, the difference between genders amounted to 2.33 for men and 2.88 for women. Using ANOVA test, the results are the following: SS= 9.507; df=1; MS=9.507, F=8.019; P=0.005. A similar result can also be found when looking at political self-identification. Individuals who align with the political left agree more with this statement than those on the political right (SS= 28.251; df=4; MS=7.063, F=6.669; P<0.001).

The following part presented negative impacts associated with the Universal Basic Income for participants to judge (*Figure 3*), based on the surveys of *Dalia Research* (2017) and *Yonder Consulting* (2018).

Figure 3: The negative impacts related to a universal basic income (n=125)

Participants were most concerned about the idea of the basic income not being tested, researched, and developed enough, with an average score of 3.79 out of 5, with increasing inflation being the second one, with an average score of 3.49. The statement about causing inflation ended up with a lot smaller average score in the original survey of *Yonder Consulting* (2018), at only 2.18, which is 1.31 less. However, with widespread price increases of everyday products and constant news about inflation, both globally and nationally, it is understandable why participants worry about a possible new type of potentially great government expenditure, which makes it hard to compare these results to the pre-pandemic ones. Regarding whether a basic income would encourage people to stop working and whether it would act as an incentive for immigrants to come to our country, statistically significant results can be found – again, based on political self-identification. Both for the work-discouraging (SS=25.282; df=4; MS=6.321; F=5.664; P<0.001) statement (*Figure 4*) and for the immigration encouraging (SS=27.875; df=4; MS=6.969; F=4,727; P=0.001) statement (*Figure 5*), those on the political right were more agreeable.

Figure 4: Political identity and the discouraging nature of a universal basic income, 1-5 Likert scale (n=125)
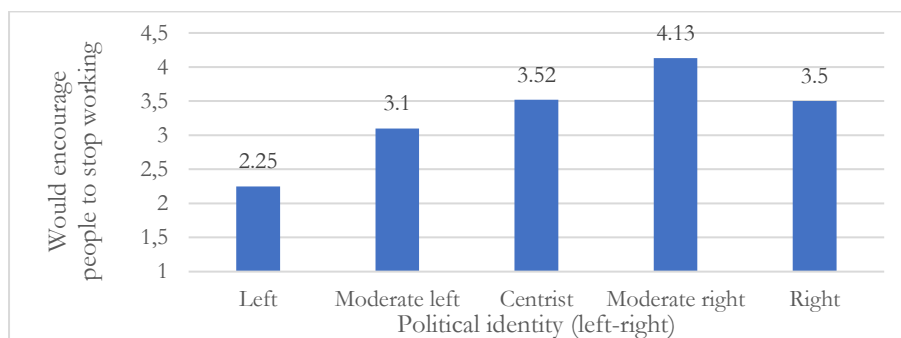
Note: SS=25.282; df=4; MS=6.321; F=5.664; P<0.001

Figure 5: Political identity and the immigration encouraging nature of a basic income, 1-5 Likert scale (n=125)
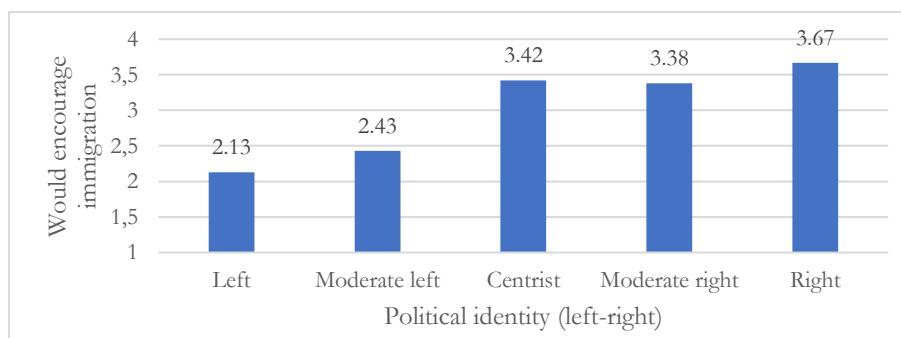
Note: SS=27.875; df=4; MS=6.969; F=4.727; P=0.001

The final question of this section and the questionnaire was about different personal changes, as well as how participants see these would be relevant to them personally. The question was based on the survey of *YouGov* (2020). The results of the question are presented in the *Figure 6*.

Figure 6: Perceived personal effects of a universal basic income (n=123)
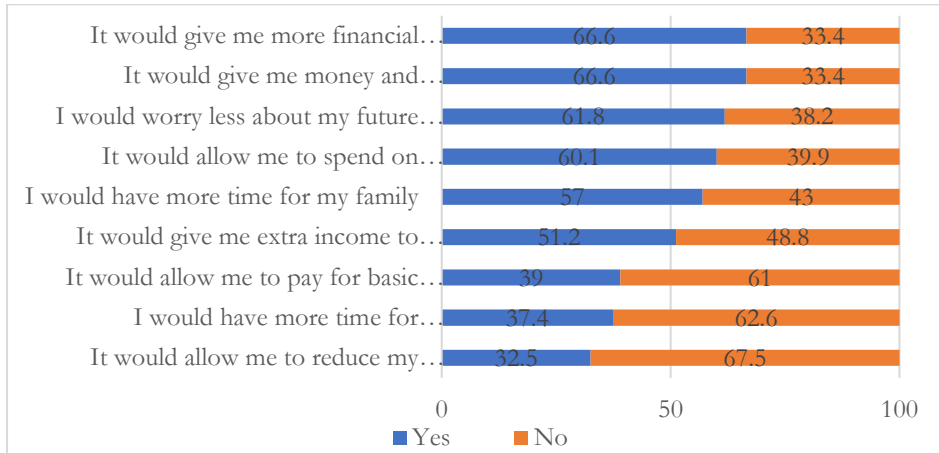
The most frequently selected two answers were about gaining financial independence and having the money and opportunity to gain further education or training. Opportunity in the second statement refers to the fact that after working, most people are not able to or allowed to go back and gain new or further education because it would be impossible to do so while working full time. With a basic income benefit, it would be possible to eliminate this trap, providing a basic standard of living that would allow workers who feel stuck in their career to adapt to a new one through education in the same ways as a basic income could solve the unemployment and poverty traps (*Clark & Kavanagh*, 1996). These options were selected a lot less often by the participants of the original YouGov survey, 29% and 19%, respectively. Investigating the statement about a basic income allowing the respondent to spend more on leisure activities (60.1%, compared to 24% in the original survey) Pearson's Chi-Square test yielded significant results regarding overall family income (Chi-Square=19.339, df=3, P>0.001; Cramer's V=0.397).

CONCLUSIONS

This study is aimed to investigate the general attitude of Hungarian citizens to basic income. In one of the most frequently cited reports of the topic, the 8th Round of the European Social Survey, Hungary was one of the countries with the highest level of support (*Lee*, 2018). To further investigate this issue, we used the surveys already tested and conducted while focusing on background variables that might have a significant influence on an individual's attitude to basic income. To conclude, we can

say that support for a basic income is considerably higher than in the European Social Survey mentioned before. For background variables, it can be concluded that the most important one is in line with the literature – political self-identity or self-placement is the most significant determinant of an individual's attitude to a basic income.

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THE INFLUENCE OF MARKETING COMMUNICATION CHANNELS ON THE MOTIVATIONS, CONSUMPTION BEHAVIOR, AND SATISFACTION OF DOMESTIC TOURISTS IN KENYA

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ABSTRACT

As one of the oldest forms of tourism, domestic tourism remains vital for any destination especially in this post Covid-19 era when tourists are extremely sensitive to cross-border travel. Therefore, an understanding of how marketing communication channels affect the motivation, consumption behavior and satisfaction of domestic tourists is crucial in promoting this form of tourism. This study aims to investigate the influence of marketing communication channels on the motivations, consumption behavior and satisfaction of domestic tourists visiting Machakos People's Park, in Kenya. To achieve this, a survey was conducted on a sample of 258 domestic tourists visiting Machakos People's Park. Quantitative data was collected through a structured questionnaire and analyzed by descriptive and inferential statistics using SPSS software. Explorative factor analysis was performed to distinguish the push and pull motivation factors, and descriptive measures were determined. Thereafter, cross-tabulation and chi-square determination were performed to test the associations between marketing communication channels and the other variables in the study. An alpha level of .05 was used for these statistical tests. The findings revealed that marketing communication channels had a significant influence only on the consumption behavior of domestic tourists but not on their motivations and satisfaction. These findings are instrumental for the marketing communication and management of Machakos People's Park, and similar domestic tourist destinations.
Keywords: cross-travel tourism, Machakos People's Park, structured questionnaire, push and pull motivation, marketing strategy
JEL codes: M31, Z33

INTRODUCTION

Tourist behavior is the way tourists behave as determined by their attitudes towards a certain tourism product and their response to using the product (*March & Woodside*, 2005). The knowledge of tourists' behavior has practical significance for the stake-

holders of the entire tourism sector (*Pearce,* 2005). Research on this subject has been conducted widely to assist tourism marketing and product planning and development with the ultimate goal of increasing the number of tourists who visit destinations (*Van Vuuren & Slabbert,* 2011). Literature indicates that this behavior is influenced by various factors including motivation, attitude, perception, individual factors, physical and built environment, and expectations (*Barajas,* 2021). Usually, it is manifested in the way tourists select their product, plan their trips, purchase their services, consume tourist products, and evaluate the services, their feedback, and propensity to revisit destinations or repurchase products (*Juvan et al.,* 2017). Consequently, motivations, consumption behavior and satisfaction of tourists have been among the major subjects in tourism research today.

Tourist motivation, defined as the driving force that determines tourists' behaviour, is closely associated with tourist behavior (*Schuckert et al.,* 2015; *Pratminingsih et al.,* 2014; *Pesonen, et al.,* 2011) and tourist satisfaction (*Wong et al.,* 2013); *Correia et al.,* 2013). According to *Barutçu et al.* (2011), there are two types of motivation: push motivations, which are related to the internal and emotional desires such as rest and self-actualization and pull motivations, which are related to cognitive and external factors such as climate, facilities and landscape. Push and pull factors have been employed quite extensively in assessing tourists' travel motivations (*Kanagaraj & Bindu,* 2013; *Yiamjanya & Wongleedee,* 2015; *Michael et al.,* 2017; *Wijaya et al.,* 2018). Both of these factors determine the decision that a tourist makes to visit a place (*Mehmetoglu & Normann,* 2013).

On the other hand, tourist satisfaction, which is defined as the level of positive feelings emanating from tourists' experience at a destination (*El-Adly,* 2019), is determined by tourists' experiences. Based on *Sturgeon et al.* (2015) satisfaction reflects both an emotional and cognitive phenomenon. Extant literature indicates that tourist's satisfaction is determined by many factors including perceived quality of experience, the cost of the stay, expectations, perceived quality of destination attributes, and tourist motivations (*Osiako et al.,* 2022; *Yun & Pyo,* 2016; *Suanmali,* 2014).

Marketing communication and sources of tourist information

When making choices and decisions related to their trips, tourists consult a large number of marketing communication channels. Particularly, the information can be categorized as offline: for instance, travel magazines and brochures, and online: for instance, online reviews and destination websites; commercial: that is; tourism-business related and non-commercial: for example, relatives and friends (*Paraskevaidis & Andriotis,* 2015), external: for example, destination website or internal: for instance, destination familiarity and prior experience (*Toyama & Yamada,* 2012). In recent times, the internet has extensively pervaded the tourism and hospitality industry.

Based on the discovery of *Pantano et al.* (2017), the propensity of purchasing online reaches its highest point with people aged 30 to 49 years. On the contrary, older tourists consider offline methods (*Bi & Kim,* 2020), while young people, although they have a positive approach towards online media (*Di Pietro & Pantano,* 2013), purchase less due to insufficient financial resources or lack of credit cards to pay

online. *Del Chiappa and Balboni* (2019) believe that millennials consider word of mouth and guidebooks as reliable travel information sources while old adults tend to prefer tour operators and travel agencies. According to earlier literature, information search also varies with gender where the majority of the studies recorded that more males use internet as compared to females (*Bi & Kim, 2020*). *Zhu et al.* (2013) stated that the exact nature of the communication media not only evolves but also changes and that people's trust in diverse media also changes and evolves (*Haddow & Haddow,* 2013).

Basic indicators of domestic tourism in Kenya

Domestic tourism is defined as the activities undertaken when residents visit places for tourism within their country of origin (*Mapingure,* 2018). The *UNWTO* (2020 cited in *TRI,* 2021) has observed that domestic tourism at the global level performs far much better than international tourism by over six times in terms of tourist trip numbers. Before Covid-19 *WTTC* (2018) reported that this form of tourism was a significant source of tourism earnings in China, Brazil, India, Argentina and Germany, as well as Japan, Mexico, the UK and the US. Despite being a notable destination in Africa, Kenya in the past appeared to over-rely on international tourism (*Manono & Rotich,* 2013; *MToW,* 2018; *Osiako & Szente,* 2021). The tourism sector is a major economic contributor to the country's Gross Domestic Product (GDP) at 10.4% and directly employs 990,000 jobs (*TRI,* 2021). Additionally, tourism statistics in the country have indicated a gradually improving domestic tourism performance in recent years, where local trips to recreational areas have appeared to be picking pace. Correspondingly, there has been growth and expansion in the number of recreational facilities, centers and activities in the country. This has both been caused by and resulted from accelerated local leisure-related activities, especially in and adjacent to major urban centers such as Nairobi, Nakuru, Mombasa, Kisumu and Eldoret. Earlier studies carried out on domestic tourism in Kenya have exhibited a paucity of comprehensiveness in scope and content, leaving many aspects of domestic tourism in need of research attention (*Osiako & Szente,* 2021).

One of the areas that needs investigation is how marketing communication channels of domestic tourists influence their motivations, consumption behavior, and satisfaction. Given that domestic tourists receive information from diverse sources, there was a need for a more focused study aimed at understanding how these factor influences motivations, consumption and satisfaction. As Kenya strives to maximize the benefits of tourism as espoused in the various policy documents (*GoK,* 2007; *MToW,* 2020) such knowledge is crucial to inform about the development of a sustainable domestic tourism sub-sector. Citing examples from Kenya, *Ndivo et al.* (2012) argued that information sources help create destination awareness, as well as aid in the making of the final destination choice. Related to this, and in the Kenyan domestic tourism situation, *Kamau et al.* (2015) found that marketing communication channels were significant in creating awareness of tourist destinations in Kenya. Hence, Hypotheses 1a to 3b are hereby stated. Therefore, this study was carried out in Machakos People's Park with the aim of achieving the following three objectives:

1. To establish the influence of marketing communication channels on the motivation of domestic tourists.

2. To establish the influence of marketing communication channels on the consumption behavior of domestic tourists.
3. To establish the influence of marketing communication channels on the satisfaction of domestic tourists.

To achieve the above objectives, the following hypotheses were tested:

H1a - There is a relationship between domestic tourists' source of information and their push motivations for visiting recreation sites.

H1b - There is a relationship between domestic tourists' source of information and their pull motivations for visiting recreation sites.

H2a - There is a relationship between domestic tourists' source of information and their re-visitation behavior for recreation sites.

H2b - There is a relationship between domestic tourists' source of information and their frequency of visiting places similar to MPP.

H2c - There is a relationship between domestic tourists' source of information and the time they spent at recreation sites.

H2d - There is a relationship between domestic tourists' source of information and their company type while visiting recreation sites.

H3a - There is a relationship between domestic tourists' source of information and their product experience while visiting recreation sites.

H3b - There is a relationship between domestic tourists' source of information and their overall satisfaction when visiting recreation sites.

MATERIALS AND METHODS

Area of study

Data for the current study was obtained from Machakos People's Park (MPP). The Park is found in Machakos County, Kenya. The recreational park is a forty-acre gated site, which is open to the public on Thursday afternoons, Friday, Saturday and Sunday. It comprises of landscaped lawns, play area for children, walkways, restaurants and an arena that hosts concerts and other social events. Adjacent to the main park is Maruba Dam, a man-made lake where boat tours are offered for a fee. Entry to the park is free for individuals and groups of less than ten people. However, these visitors pay for the various individual recreational services they choose to enjoy inside the park. This study considered this recreational park for understanding domestic tourism.

Research design and variable measurements

This study used cross-sectional questionnaire survey to collect quantitative data by structured questions. The variables of interest in this study are domestic tourists' socio-demographic characteristics, the source of first information about MPP, the most satisfying experiences, satisfaction levels, and frequency of consumption/visiting such places. The motivation variables for this study are developed basing on previous conceptualizations and studies in the context of leisure tourism and modified in relation to the area under study (*Yiamjanya & Wongleedee*, 2015; *Xu & Chan*, 2016;

Naidoo et al., 2015; *Kassean & Gassita,* 2013). Ultimately, push motivation indicator variables amount to 10 while there are 12 pull motivation indicator variables. All the 22 motivation statements considered are measured with the five-point interval scale from strongly disagree (1) to strongly agree (5). Types of product/service experiences were broken down into seven categories from which the respondents indicated the one that gave them the greatest satisfaction. These categories included 1-food, 2-drinks, 3-nature-based activities, 4-ambience, 5-entertainment, 6-outdoor recreation, and 7-socializing.

The overall satisfaction variable for this study was measured on the five-point Likert scale as follows: No satisfaction (1) Satisfaction below average (2) Average satisfaction (3), Satisfying (4), Highly Satisfying (5). As pertains to consumption behavior, visitors' re-visitation was measured by the respondents' indicating the number of times they revisited the park on a frequency scale from: nil (0), to more than five times (5). Furthermore, they were required to indicate the length of time they intended to spend in the park during the present visit, and how frequently they planned and visited recreational places similar to MPP. The last consumption behavior examined was the type of company. The main marketing channel of communication was sought by asking the respondents to indicate their first source of information about the recreation site under study. To answer this, they selected from a list that highlighted word of mouth, print media, the internet and websites, social media, happened to see the place while passing, and television and radio broadcasts. The final part of the questionnaire enquired about the respondents' socio-demographics: age, gender, education level, family status, county of origin and income.

Data collection and analysis

A cross-sectional descriptive research design was applied in this study to collect data and establish the relationships among key variables. This study targeted recreationists of Kenyan origin who visited MPP during the period of study (December 2019 and January 2020). To achieve this, a semi-structured questionnaire was used which included both open-ended and closed-ended questions. Systematic random sampling was carried out to collect data from respondents. Every fourth Kenyan adult person (over the age of 18 years) entering the park through the main entrance during the opening days (Thursday afternoons, Friday, Saturday and Sunday) was requested by the two appointed research assistants to participate in the survey by filling in the questionnaire. After being introduced to the survey and its main aims those who acknowledged to be Kenyans, and consented to participate in the study were given an opportunity to voluntarily respond to the questions. A total of 392 questionnaires were distributed, out of which 311 (79% response rate) were filled. From these, 258 (83%) were found to be complete and usable. Data was analyzed using the IBM SPSS Statistics for Windows, version 23.0 (IBM Corp., Armonk, N.Y., USA) software to determine descriptive and inferential statistics: percentages, frequencies, standard deviations, measures of central tendency, and cross-tabulation.

Socio-demographic characteristics of respondents

As indicated in *Table 1*, the sample comprised of more males (53.2%) than females (46.8%). The majority of them (55.7%) earned an income of less than 50,000 Kenyan shillings (USD 500) per month. Respondents who were married with child/ren represented the highest percentage in marital status (27.2%). As pertains to the highest level of education attained by the respondents, the biggest proportion of the sample (35.4%) were middle-level college graduates. Rural dwellers exceeded (63.9%) urban dwellers (36.1%) who visited MPP during the survey period.

Table 1: Respondents' socio-demographic characteristics (N=258)

Socio-demographic variable		Frequency	Percent
Gender	Male	137	53.2
	Female	121	46.8
Age	18-25	36	13.9
	26-35	93	36.1
	36-45	87	33.5
	46-55	31	12.0
	56-65	11	4.4
Your income	below 50,000	144	55.7
	50001-100000	65	25.3
	100001-150000	42	16.5
	over 150000	7	2.5
Your marital status	Single Without Children	67	26.0
	Single With Child/ren	51	19.6
	Married With Child/ren	70	27.2
	Married Without Children	67	26.0
	Widowed	3	1.3
Highest educational level attained	Primary	20	7.6
	Secondary	57	22.2
	College	91	35.4
	Bachelor's Degree	73	28.5
	Post Graduate Degree	16	6.3
Residence	Rural	165	63.9
	Urban	93	36.1

RESULTS

Exploratory factor analysis of the motivation variable

A five-point scale was used to measure the level and type of motivation for domestic tourists visiting MPP. The scale in the questionnaire was used to specify the level of agreeableness from 1 = strongly disagree to 5 = strongly agree. In order to determine the primary dimension of the respondents' motivation to visit MPP, an exploratory factor analysis was performed. For item inclusion, loadings of .40 were used and eigenvalues of 3.927 and 2.869 for factor extraction criterion. A total of 22 items

represented the motivational factor on which a factor analysis with Principal Component Approach and Oblimin with Kaiser Normalization was performed. To verify the normality and significance of the conducted analyses, KMO Bartlett's test was carried out and it was found to be highly significant (approximate $X^2 = 1120.390$, $df = 136$, $p < 0.0001$). The Kaiser-Meyer-Olkin's (KMO) overall measure of sampling adequacy (.805), and Bartlett's Test of Sphericity ($X^2 = 1120.390$) indicated that the data were suitable for using factor analysis (*Tabachnick & Fidell,* 2001).

EFA yielded two categories of motivation factors, which represented 40% of the total variance (*Table 2*). Cronbach's coefficients were calculated for each factor in order to determine the reliability of the analyzed data and serve as a measure of internal consistency among the identified items. From the original 22 items, items number 6, 14, 16, 21 and 22 did not load to their respective factors adequately with the set value of at least .40 and were therefore dropped. Thus, the push motivation factor was left with 9 items and the pull motivation factor with 8 items.

Table 2: Explorative factor analysis of the motivation items

Item No.	Motivation Item Statement	Item loading		Mean	Std dev.	Relia-bility
		Factor				
		[a]PushM	[b]PullM			α
1	I had saved money to spend on such a visit	.656				
2	I wanted to find relief for my ill health	.724				
3	I need a place to enjoy company of friends	.645				
4	I need for an opportunity to learn	.558				
5	I find an ideal place for my children	.559		3.34	.765	.800
6	To conduct research	.518				
7	It was recommended by friends	.507				
8	I had an incentive offer from my employer	.722				
9	I feel historically attached to this place	.658				
10	This place is a famous attraction		.596			
11	In this place I enjoy outdoor recreation		.472			
12	In this place I enjoy attractive landscape		.747			
13	The place suits my need to relax		.573	3.62	.689	.761
14	This place is easily accessible		.688			
15	I enjoy a variety of experiences		.491			
16	In this place I enjoy pleasant ambience		.718			
17	This place is affordable		.561			

Note: [a]PushM - Push Motivation; [b]PullM - Pull Motivation; Extraction Method: Principal Component Analysis. Rotation Method: Oblimin with Kaiser Normalization.

The Cronbach's Alpha coefficients for the two factors were .800 and .761 respectively. They were both above .70 and therefore sufficient for performing factor analysis.

Consumption behaviour

The majority of the respondents (36.0%) were visiting the recreational park for the first time (*Table 3*). This was followed by those visiting for the second time (25.2%) and then the third time (21.7%). These percentages were drastically reduced to a mere 4.3% for the visitors coming for the fourth time. The fifth time was represented by 5.8% and those who had visited for more than five times represented 7%. Evidently, the chances of recreationists making subsequent visits to the park marginally reduce progressively as they made some extra visit, with the chances dropping sharply after the third visit.

Table 3: Travel behavior and party characteristics (N=258)

Travel behavior		Frequency	Percent
Number of revisits to MPP	0	93	36.0
	1	65	25.2
	2	56	21.7
	3	11	4.3
	4	15	5.8
	More than 4	18	7.0
How frequently I visit similar places	Once every month	26	10.1
	More once every month	16	6.2
	Every public holiday	31	12.0
	Once a year	57	22.1
	Twice a year	42	16.3
	Occasionally	86	33.3
Travel party	I came alone	47	18.2
	I came in the company of a spouse without children	42	16.3
	I came in the company of a spouse with children	65	25.2
	I came in the company of children without a spouse	34	13.2
	I came with friend/s/colleagues	70	27.1
Duration spent at MPP	1-3 hours	105	40.7
	4-6 hours	126	48.8
	7-9 hours	20	7.8
	10 hours and above	7	2.7

Nearly half of the respondents (48.8%) spent between 4 to 6 hours at the recreational park during their visit (*Table 3*). This was followed by a 40.7% enjoying the site for up to 3 hours while 7.8% and 2.7 % represented the 7-9 hours and 10 hours and above durations, respectively. The average time spent by visitors at the MPP is 4.14 hours.

The frequency with which respondents planned and visited recreational places similar to MPP appeared to vary greatly (*Table 3*). An overwhelming majority (33.3%) indicated that such local tours are undertaken occasionally, rather unfrequently. This

strongly suggests that undertaking local tours at regular intervals is not a primary concern of most Kenyans. Those who participate in such trips once a year are 10.1% and those who do it twice a year were 16.3%. A further 12.0% engaged in such activities during public holidays those who did it more than once every month reached 6.2%.

When asked to specify with whom they visited the MPP with, a majority of the respondents (27.1%) indicated that they came in the company of friends or colleagues. The second highest percentage (25.2%) came in the company of their spouses with children, followed by 18.2% who came alone, while 16.3% came in the company of spouses without children. The least percentage (13.2%) came to enjoy in the company of child/ren without a spouse (*Table 3*).

Satisfaction with recreational experiences

The park offered a variety of recreational experiences to visitors. Considering seven categories of product and service experiences at the park, respondents were asked to indicate the category from which they derived the highest satisfaction. As indicated in *Table 4*, "outdoor recreation" and "socializing" offered the highest satisfaction among 19.8% of respondents, closely followed by "entertainment" (18.6%), "ambience" (17.4%), "nature" (17.1%), and, finally, "food and drinks" (7.4%). When asked to rate the overall satisfaction they received in the park, the majority (49.2%) described the overall experience as "satisfying". The rating scale ranged from "1 = no satisfaction" as the lowest score, progressing through "2= satisfaction below average", "3 = average satisfaction", "4 = satisfying" and finally "5 = highly satisfying" (*Table 4*).

Table 4: Satisfaction (N = 258)

Product/service experience		Frequency	Percent	Mean	SD
Most satisfying service experience	Drinks	7	2.7	4.73	1.682
	Food	12	4.7		
	Nature-Based Activities	44	17.1		
	Ambience	45	17.4		
	Entertainment	48	18.6		
	Outdoor Recreation	51	19.8		
	Socializing	51	19.8		
Level of satisfaction	No Satisfaction	4	1.6	3.95	.885
	Satisfaction Below Average	13	5.0		
	Average Satisfaction	44	17.1		
	Highly Satisfying	70	27.1		
	Satisfying	127	49.2		

Tourists' source of information

In order to establish the channels through which visitors to the park heard about the existence of MPP for the first time, respondents were asked to indicate how they came to learn about the park for the first time. It turned out that word of mouth (WOM) from friends and relatives was the most common channel of marketing

information at 38.8%. Next came newspapers and other print media (17.1%), then internet and websites (14.0%), followed by social media (12.0%). Those who happened to know the place by seeing it while passing by represented 11.6%, and finally, television and radio broadcasts 6.6% (*Table 5*).

Table 5: Tourists' source of information (N = 258)

Source	Frequency	Percentage
Word of mouth (WoM)	101	38.8
Print media	44	17.1
Internet and websites	36	14.0
Social media	31	12.0
Happened to know by passing by	29	11.6
Television and radio broadcasts	17	6.6

Influence of marketing information channels on domestic tourism

To determine the influence of marketing information channels on domestic tourism, these variables were cross-tabulated with three variables: motivation, consumption behavior and satisfaction. *Table 6* summarizes the results and gives the respective chi-square test values and implications for the associations.

As indicated in *Table 6*, the sources of destination information only influenced consumption behavior but had no influence on the motivations and satisfaction of domestic tourists.

Table 6: Chi-square test results for cross-tabulating marketing information channels with motivation, consumption behavior and satisfaction

Mea-sure	Motivation		Consumption behavior				Satisfaction	
	PushM	PullM	Revisi-tation	Frequ-ency of visit	Time Spent	Com-pany type	P/S Exp	OS
χ^2	125.357	120.307	54.200	50.021	27.785	41.371	29.889	30.601
df	120	120	25	30	15	20	30	20
p-value	.351	.475	.001	.012	.023	.003	.471	.061
Influence	NO	NO	YES	YES	YES	YES	NO	NO

Note: PushM – Push motivations; PullM – Pull motivations; P/S – Product/Service experience; OS – Overall satisfaction.

Results of hypotheses testing

With regard to the hypotheses tested, this study established that contrary to H1a and H1b, there was no relationship between domestic tourists' sources of information and their push motivations for visiting MPP, nor between domestic tourists' sources of information and their pull motivations for visiting MPP respectively. Hence, domestic

tourists' sources of information had no influence on their motivations for visiting MPP (H1 was not supported). H2a, H2b, H2c, and H2d were supported, since there was a relationship between domestic tourists' sources of information and the behavior of re-visiting MPP, the frequency of visiting places similar to MPP, the length of time they spent at MPP, and their company type when vising MPP, respectively. Hence, domestic tourists' sources of information fully influenced their consumption behavior (H2 was supported). Contrary to H3a and H3b, there was no association between domestic tourists' sources of information and their product experience while visiting MPP, nor between domestic tourists' sources of information and their overall satisfaction when visiting MPP, respectively. Hence, domestic tourists' sources of information had no influence on their product experience and satisfaction (H3 was not supported). The results of hypotheses testing are indicated in *Table 7*.

Table 7: Results of hypotheses testing

Hypothesis		Relationship tested	Decision
1	1a	Marketing comm. channels → Push Motivation	Not Supported
	1b	Marketing comm. channels → Pull Motivation	Not Supported
2	2a	Marketing comm. channels → Re-visitation	Supported
	2b	Marketing comm. channels → Similar places	Supported
	2c	Marketing comm. channels → Duration spent	Supported
	2d	Marketing c comm. channels → Company type	Supported
3	3a	Marketing comm. channels → Product Experience	Not Supported
	3b	Marketing comm. channels → Overall Satisfaction	Not Supported

DISCUSSION

Influence of marketing communication channels on domestic tourism

This study established that word of mouth (WOM) from friends and relatives was the most common channel through which the majority of the domestic tourists learnt about the existence of MPP. The poorest channel for informing them about the park was television and radio broadcasts. It therefore appears that information about the attractiveness of such attractions was already in the public domain, especially through person-to-person communication. Accordingly, *Barak et al.* (2017) earlier observed that visitors to Machakos County as a destination in Kenya could obtain as much information about the county as they needed before they visited. Thus, corroborating our argument and that of *Ndivo et al.* (2012) according to which the necessary information about destinations in Kenya was well sufficient in the public domain.

However, with regard to the variables in the current study, having WOM as the predominant marketing channel of communication had a positive influence only on the consumption behavior of domestic tourists. It had no influence on their motivations and satisfaction (Objective 1 & 3). Considering that pull and push motivations are the starting point of any visitor's decision (*Battour et al.,* 2012), and that motivations prompt the evaluation that visitors could make about a certain destination, the findings of this study imply that there is no particular channel that

strongly influences tourists' decision making and evaluation of this destination (motivation). Equally, since satisfaction emanates from prior expectations, it showed that the channels of communication did not create an expectation in the mind of the tourists to the point that they influenced their ultimate satisfaction.

The findings above are partly in line with the arguments of *Murphy et al.* (2007 cited in *Shen et al.*, 2018) who observed that the influence of friends, relatives or other tourists can affect tourists' consumption and satisfaction. It follows that the way messages are passed to domestic tourists will directly or indirectly determine their consumption behavior (Objective 2). Considering the current research, the consumption behavior in question could comprise of repeat visiting, touring other attractions that were similar in nature to MPP, spending considerable time at the attraction, and being in the company of particular types of individuals when visiting the recreation sites. The predominance of WOM as the primary source of tourism information as indicated in the current study could mean that only a small proportion of the potential audience was reached by marketing information. This situation calls for deliberate efforts by tourism product marketers and destination management organizations (DMOs) to additionally leverage on the rapidly expanding digital promotional channels. They need to enhance the exploitation of modern technology; especially socio-media and other internet-based marketing opportunities.

Furthermore, it is worth noting that some earlier studies found results that were contrary to the current findings. For example, *Sawagvudcharee* (2019) did not find a straightforward relationship with respect to domestic tourism and information sources.

CONCLUSIONS

In conclusion, marketing information channels proved to be an important factor only with regard to the consumption behavior of domestic tourists. These channels determined domestic tourists' re-visitation tendency, visitation to similar places, time spent at recreation sites, and the type of people in the company of whom they enjoy recreational products and services. Since WOM was predominant in this case, it follows that for an effective tourism promotion, marketers of tourist destinations should endeavor to leverage on this premise to communicate to prospective domestic tourists to improve their consumption behavior. It was however noteworthy that, marketing communication channels had no bearing on domestic tourists' motivations and satisfaction but the exact reason for this requires further research.

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DEFENCE ACQUISITION: A WICKED PROBLEM?

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ABSTRACT

Defence acquisition is a complex undertaking involving multiple actors and processes. However, in recent years, the US and UK defence acquisition frameworks have been criticised for not being able to cope with the complex and uncertain nature of defence. The paper takes this criticism and argues that defence acquisition is best understood as a "wicked problem" in which collective processes tie the system into large and interconnected networks of systems, not as a traditional linear science problem. In particular, the paper demonstrates that the Linear Transformation Model, at the heart of the US and UK defence acquisition framework, is ill-designed to cope with the complex and uncertain nature of both defence outputs and outcomes. The main reasons are technological maturity, information asymmetry and the need for interpretation and judgement. Furthermore, the paper elaborates that defence acquisition is characterised by a "problem of theory" and a "problem of practice" and that further research is necessary in order to transform its institutional culture and tackle the theory-practice divide with a more holistic approach.
Keywords: linear transformation model, second generation systems approach, theory-practice divide, advanced weapon systems

INTRODUCTION

"Acquisition is how we work together with industry to provide the necessary military capability to meet the needs of our Armed Forces now and in the future. It covers the setting of requirements; the selection, development and manufacture of a solution to meet those requirements; the introduction into service and support of equipment or other elements of capability through life, and its appropriate disposal." (*MOD*, 2022)

The above quote from the *UK Ministry of Defence* (MOD) suggests that defence acquisition is a complex undertaking involving multiple actors and processes. Indeed, by contrast to procurement, which refers to a single (and simple) public activity of contracting with a provider to buy a good or a service, acquisition describes a complete cycle with different phases, milestones and key decision points (*Lefeez*, 2017a). For example, the UK Smart Acquisition Framework identifies six phases (Concept, Assessment, Demonstration, Manufacture, In-Service and Disposal), and three key approval points: Strategic Outline Case (SOC), Outline Business Case (OBC) and Full Business Case (FBC) (*Figure 1*).

Figure 1: UK's Defence Acquisition Framework: CADMID
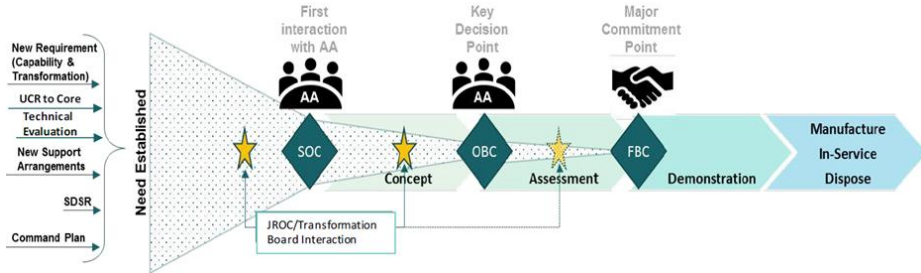
Source: *MOD*, 2022, p. 14

The US Major Capability Acquisition Model identifies five phases (Material Solution Analysis, Technology Maturation and Risk Reduction, Engineering and Manufacturing Development, Production and Deployment, and Operations and Support), there milestone decisions (Milestone Decisions A, B and C) and four critical decision points (Material Development Decision, CCD Validation, Development RFP Release Decision and Full Rate Production/Full Deployment Decision) (*Figure 2*).

Figure 2: The US Major Capability Acquisition Model
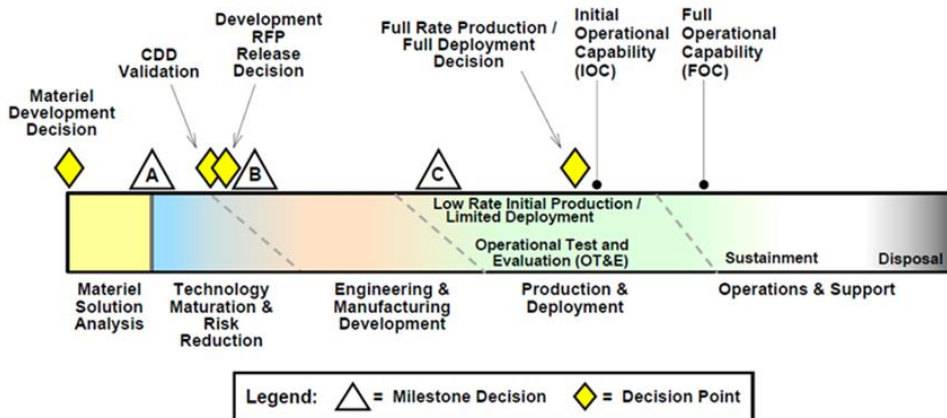
Source: *DOD* (2021, p. 10)

However, in recent years, the US and UK frameworks have been criticised for not being able to cope with the complex and uncertain nature of defence and defence acquisition (see *Rendon & Snider*, 2019; *Burgess & Antill*, 2017). The paper takes up this criticism and argues that defence acquisition is best understood as a "wicked problem" (*Rittel & Webber*, 1973) and not as a "linear science problem" as suggested by the US and UK frameworks. The difference is crucial. While traditional science problems can be dissected into smaller, segregated (bounded) systems and addressed by a cybernetic cycle of governance as in *Deming's* (1984) plan-do-check-act framework, in wicked problems, the collective processes tie the systems into large

and interconnected networks of systems, such that outputs from one system become inputs to another system (*Rittel & Webber*, 1973, p. 159). It is therefore less apparent where the centre of the problem lies and where and how to intervene. *Rittel & Webber* (1973) defined ten distinguishing properties of wicked problems (*Table 1*).

Table 1: The ten properties of wicked problems

Nr	Property
1	There is no definitive formulation of a wicked problem.
2	Wicked problems do not have an exhaustive describable set of potential solutions, nor is there a well-described set of permissible operations that may be incorporated into the plan.
3	Every wicked problem can be considered to be a symptom of another problem.
4	The existence of a discrepancy representing a wicked problem can be explained in numerous ways. The chosen explanation determines the nature of the problem's resolution.
5	Wicked problems have no stopping rule.
6	Solutions to wicked problems are not true-or-false, but good-or-bad
7	Every solution to a wicked problem is a "one-shot operation"; because there is no opportunity to learn by trial-and-error, every attempt counts significantly.
8	The planner has no right to be wrong.
9	There is no immediate and no ultimate test of a solution to a wicked problem.
10	Every wicked problem is essentially unique.

Source: Based on *Rittel & Webber* (1973)

LITERATURE REVIEW

As indicated in the introduction, defence acquisition is plagued by various challenges. The literature review discusses these challenges. One of the primary issues in defence acquisition is the high costs of military equipment and services. According to *Smith* (2022) and *Hartley* (2020a), cost overruns are common in defence acquisition programmes and frequently result in delayed delivery and reduced performance. The authors identify (technological) uncertainty and the dominance of government as a monopsony customer precluding a market in weapons as key factors. However, the authors also deplore the scarcity and unavailability of reliable data (*Hartley*, 2020a, p. 72). Tackling this data shortage gap, *Etemadi* (2020) examined major defence acquisition programmes (MDAPs) in the US from 2007 to 2018 and found that on average, it takes the *Department of Defense* (DOD) about eight years to deliver a new system (or new capabilities) to the operating forces using existing acquisition processes. His study attributes delays and cost overruns to multiple factors, including the adaptation of user requirements, the pace of technology and adversary change, and inefficient management practices. Similarly to *Etemadi* (2020), *Jones* (2022) also reviewed US MDAPs and identified a statistically significant difference between the Cost Growth Factors (CGFs) between the 1990s and the 2010s, with the 2010s exhibiting lower CGFs than the 1990s. She explains this variance by different reform cycles, where the reforms of the 2010s era, which focus on restricting Acquisition,

Technology and Logistics, proved more efficient than the reforms of the 1990s era, which aims to mandate for Change and Transformation.

Jones's (2022) research findings are backed by *Ahner et al.* (2019), who demonstrate that the *DOD* has significantly improved its decision-making culture by introducing the scientific test and analysis techniques (STAT) in its test and evaluation (T&E) process in 2012. Following the authors, STAT has become a key element, not only for generating the knowledge to mature existing technologies that fulfil a requirement gap (e.g. F-35 combat aircraft) and to inform on the performance of new technologies (e.g. autonomous systems), but also for lowering the costs of MDAPs (*Ahner et al.*, 2019).

In a similar vein, the 2022 and 2021 Annual Assessment reports by the *Government Accountability Office* (GAO) identified cost overruns as significant challenges in defence acquisition. The reports found that the DOD has experienced cost overruns in several key programmes, including the F-35 combat aircraft, the Ford-class aircraft carrier (i.e. CVN-78) and the Zumwalt-class destroyer. Among others, the report urges the DOD to improve its cost estimation processes and to use more accurate data for assessing the financial impacts of its MDAPs (*GAO*, 2022; *GAO*, 2021). A 2022 report by the RAND Corporation confirms the criticism expressed by GAO and underscores that there is no one-size-fits-all approach that works with every defence acquisition programme (*Wong et al.*, 2022). The report highlights that attempts to force programmes into a single paradigm lead to problems and inefficiencies. The authors recommend tailoring acquisition strategies, organizational roles and responsibilities and reporting structures to the unique characteristics of each programme (*Wong et al.*, 2022).

However, cost overruns can also result from unforeseen events such as the COVID-19 pandemic. The pandemic has disrupted global supply chains and impacted the delivery of equipment and services, leading to cost increases and schedule delays in many sectors, including defence (*Panwar et al.*, 2022; *Lopes Pimenta et al.*, 2022). The fiscal year (FY) 2020 Annual Report from the *Director Operational Test and Evaluation* (DOT&E) highlights that the changes DOT&E services and agencies instituted in response to the pandemic affected T&E for one-third of the programmes under its oversight (i.e. 75 programmes) (*DOT&E*, 2021). Action officers participated only in events deemed mission-essential such as live fire and operational tests for the F-35 and CVN-78 programmes. Likewise, a report commissioned by the European Parliament in 2021 points out that the COVID-19 pandemic has accentuated already recognised capacity shortfalls of the EU Common Security and Defence Policy (CSDP), including strategic airlift, secure communications and command and control (*Meyer et al.*, 2021).

A further area of concern in defence acquisition is the lengthy procurement process, which refers to the delays and other obstacles that can arise during the process due to complex regulations, procedures, and organisational hierarchies (*Šumpíková & Ďurčeková*, 2019). A 2021 defence efficiency report from the *National Audit Office* (NAO) notes that the UK MOD and its suppliers have both contributed to schedule delays across the contracted programmes that it investigated, resulting in shortfalls in the defence capability of the UK Armed Forces (*Davies*, 2021). NAO highlights that overall, the MOD faces cumulative forecast net delays to equipment

entering into service of 254 months across 13 programmes. Importantly, NAO sees that the causes for delays are multi-factorial, ranging from over-optimistic schedules and supplier performance to contract management and departmental austerity measures (*Davies*, 2021).

By contrast to NAO, *van Weele & Essig* (2017) trace a lengthy procurement process back to complex procurement regulation, most notably the EU Defence Procurement Directive 2009/81/EC, and stress that the public sector lacks a professional procurement system and adequate specialists. In particular, the authors emphasise that whilst EU procurement regulations make a lot of sense in their own right, many EU governments are simply unable to implement them in a meaningful way and make extensive use of exceptions such as Article 346 of the Treaty on the Functioning of the European Union, allowing a member state to divert from EU procurement regulation in order to protect their essential security interests (*van Weele & Essig*, 2017).

Closely connected to the procurement process issue is the question of transparency, as a lack of transparency can lead to corruption, mismanagement and inefficient allocation of resources. In his review of the Belgian defence acquisition system, *Reykers* (2021) shows that parliamentary oversight can help prevent corruption, reduce wasteful spending and ensure that defence procurement meets the needs of the military end-users. One of the key lessons from the Belgian experience is the importance of early engagement by parliament in the defence acquisition process. The Belgian parliament, via its Defence Committee, is involved in the planning and development stages of military procurement projects, which allows the committee to provide feedback and make recommendations to the government. This early engagement can help ensure that defence programmes are aligned with the strategic and operational needs of the military and that potential issues are addressed early on. The committee furthermore provides valuable inputs to the government, which publishes an annual report on defence acquisition, containing information on the contracts awarded to the defence industry (e.g. value, nature of the system, and others) (*Reykers*, 2021).

Another challenge in defence acquisition is the lack of consistency in procurement data and reporting. A 2021 NAO report highlights that the UK MOD lacks accurate information on the progress of some programmes, which in turn makes it difficult to monitor suppliers' performance (*Davies*, 2021). This criticism is echoed by the 2022 and 2021 GAO Annual Assessment reports (*GAO*, 2022; *GAO* 2021). However, NAO acknowledges that the MOD has taken steps to address the procurement data and reporting issue, for example by introducing earlier support and scrutiny to programmes in order to identify gaps in knowledge and by applying *Earned Value Management* (EVM) techniques to measure supplier progress more accurately (e.g. Crowsnest radar system) (*Davies*, 2021).

The reports by NAO and GAO are in line with the recent academic literature on the governance of the principal and agent relationship, which emphasises the need for formal control and coordination mechanisms, including penalties and incentive schemes (see *Aben et al.* 2021; *van Strien et al.*, 2019. However, these studies also highlight that a contractual approach on its own is not sufficient for managing the buyer-supplier relationship and needs to be complemented by relational factors such as trust, open communication and the co-creation of value. In fact, the studies

confirm the need for a "third way" in defence acquisition; a way that lies between the cost-plus contracts of the post-World War II era and the fixed price contracts of the post-Cold War era (*Wylie*, 2017; *Roehrich et al.*, 2014; *Caldwell & Howard*, 2011; *Markowski et al.,* 2010; *Lewis & Roehrich*, 2009).

Some countries such as the UK show sign of embarking on such a "third way" trajectory. Following the 2021 Defence and Security Industrial Strategy (DSIS), the UK is taking a more protective industrial stance in the future and is doing away with its competition by default policy (*MOD*, 2021). DSIS cites the UK's departure from the EU as an opportunity to reform its Defence and Security Public Contracts Regulations that were devised in 2011 in compliance with EU Defence Procurement Directive 2009/81/EC. The new strategy seeks to provide strong support for defence exports through increased clarity on programme requirements and the use of a new government-to-government commercial mechanism, with the US being a key strategic partner here (*McGerty*, 2021).

A further concern in defence acquisition is the consolidation of the defence sector. Today, the defence sector is dominated by only a few firsttier giants operating as system integrators and hosts of second and thirdtier suppliers supporting the activities of these giants (*Tian*, 2020; *Fonfría & Sempere*, 2020). On the US side, these defence giants are Lockheed Martin, Northrop Grumman, Raytheon, Boeing and General Dynamics. On the European side, the defence giants are BAE Systems, Airbus, Thales and Leonardo (*SIPRI*, 2022). A 2022 report from the Office of the *Under Secretary of Defense for Acquisition and Sustainment* (USDA&S) considers competition within the defence industrial base vital, arguing that competition incentivizes innovation by driving the industry to offer its best technical solutions at a best-value cost and price (*USDA&S*, 2022). However, the report deplores that since the 1990s, the defence sector has consolidated substantially, transitioning from 51 to 5 aerospace and defence prime contractors. Most importantly, the report assesses this as a significant national security risk, most notably because a dominant supplier can easily be influenced by an adversary nation (*USDA&S*, 2022).

Another issue in defence acquisition is the ongoing use of immature technologies. A 2020 GAO study identifies a low technology readiness level (TRL) as an important driver of rising unit costs and lead-time overrun (*GAO*, 2020a). The study demonstrates that MDAPs with a low TRL have suffered from important cost growth and schedule delays, whereas MDAPs with a high technology TRL have stayed within their initial budget and time boundaries (*Table 2*). This criticism is not new, however. For example, *Bailey et al.* (2014) deplore that in spite of the rising evidence that programmes with immature technology experience cost, schedule, and performance shortfalls, US military services (e.g. Army, Navy and Air Force) exhibit a strong tendency to ignore this fact (*Bailey et al.*, 2014). Similarly, *Pennock* (2015, 2008) underscores that despite changes in the acquisition regulations to encourage a more evolutionary approach to systems development (e.g. STAT), which require the use of more mature technologies, MDAPs continued to rely on immature technologies. *Pennock* (2015, 2008) traces this behaviour back to a tragedy of the commons in which the different US military services (e.g. Army, Navy and Air Force) are overexploiting the commons (here: MDAPs); the reason being that there is no cost for them to do so.

Table 2: US Cost and Schedule Experiences for Products with Mature and Immature Technologies

Product development			
Product development and associated technologies	TRL at program initiation	Cost growth	Schedule delay
Comanche helicopter		101 percent	120 percent
- Engine	5		
- Rotor	5		
- Forward-looking infrared	3		
- Helmet-mounted display	3		
- Integrated avionics	3		
Brilliant anti-armor submunition		88 percent	62 percent
- Acoustic sensor	2		
- Infrared seeker	3		
- Warhead	3		
- Inertial measurement unit	3		
- Data processors	3		
Hughes HS-702 satellite		None	None
- Solar cell array	6		
Ford Jaguar automobile		None	None
- Adaptive cruise control	8		
- Voice-activated controls	8		

Source: Based on *GAO*, 2020a, p. 27

Finally, a last constraint in defence acquisition is the importance of national security interests, which has negatively impacted international collaborative acquisition programmes. For example, *Calcara* (2018) investigated four European collaborative aircraft programmes (NH90, A400M, Eurofighter and Tornado) and concluded that in each instance, relative gains considerations were crucial to explaining a member nation's preference towards cooperation. Most importantly, *Calcara* (2018, p. 493) stresses that 'in spite of the potential absolute gains in pursuing joint initiatives in the defence-industrial landscape', European governments and industries are hesitant in sharing defence technologies which have been developed with national resources and they need to consider how technology transfer could strengthen rivals' position in the regional and global market'.

Calcara's (2018) findings are supported by *Kanniainen & Lehtonen* (2020), who, by drawing on a game theory model, identify four reasons why collaborative defence acquisition is more of an exception in NATO and the EU than the rule: First, key user requirements are nation-specific with important implications for national security. Second, nations that place a low value on a weapon system have more bargaining power than nations that place a high value on a weapon system and may require a side payment to enter a procurement collaboration that the other side is not willing to pay. Third, the potential gains from cooperative procurement, namely economies of scale and increased knowledge and technology transfer, may not be sufficient to compensate for

conflicting key user requirements. Fourth, short-term optimism tends to prevail over long-term commitment (*Kanniainen & Lehtonen*, 2020, p. 201).

METHODOLOGY

Building on the insight gained from the literature review and on insights from his own research on no-capability defence acquisition (see *Verlaine,* 2022a; 2022b; in press-a, in press-b), the author assumes that the following eight properties of *Rittel & Webber's* (1973) wicked problems also have relevance in defence acquisition:

(1) There is no definitive formulation of a wicked problem.
(2) Wicked problems do not have an exhaustively describable set of potential solutions, nor is there a well-described set of permissible operations that may be incorporated into the plan.
(3) Every wicked problem can be considered to be a symptom of another problem.
(4) The existence of a discrepancy representing a wicked problem can be explained in numerous ways. The chosen explanation determines the nature of the problem's resolution.
(5) Wicked problems have no stopping rule.
(6) Solutions to wicked problems are not true-or-false, but good-or-bad
(7) Every solution to a wicked problem is a "one-shot operation"; because there is no opportunity to learn by trial-and-error, every attempt counts significantly.
(8) The planner has no right to be wrong.

The author investigates each of these properties separately through the lens of a second-generation systems approach (that is an approach which accounts for the networked structure and collective workings in defence acquisition) and tests them against their explanatory power and empirical validity. The analysis is informed by political, economic and management theory and classical concepts such as institutional logic (*Friedland & Alford*, 1991), experiential learning (*Kolb*, 1984), competitive advantage (*Porter*, 1985), dynamic capabilities (*Teece et al.*, 1997), and organisational ambidexterity (*O'Reilly & Tushman*, 2013).

ANALYSIS AND DISCUSSION

There is no definitive formulation of a wicked problem

Following *Rittel & Webber* (1973, p. 161), the information needed to understand a wicked problem depends upon one's ideas for solving it. Moreover, in order to describe the problem in sufficient detail, one has to develop an exhaustive inventory of all conceivable solutions ahead of time. The dilemma however is that in order to anticipate all questions, knowledge of all conceivable solutions is required. The US and UK defence acquisition frameworks presuppose such knowledge. In fact, they follow a linear transformation logic in which inputs are converted through processes into outputs and outcomes (*Figure 3*).

Especially with the introduction of the neoliberal reform agenda and its efficiency policies (i.e. New Public Management), the Linear Transformation Model has gained

popularity, not least because of its promise to deliver greater value-for-money, where value-for-money is defined as the ratio between economy (spending less on inputs), efficiency (output relative to the input) and effectiveness (a measure of the impact achieved) (*Wylie*, 2017, p. 168). However, the overall success of the Linear Transformation Model is mixed.

Figure 3: The Linear Transformation Model
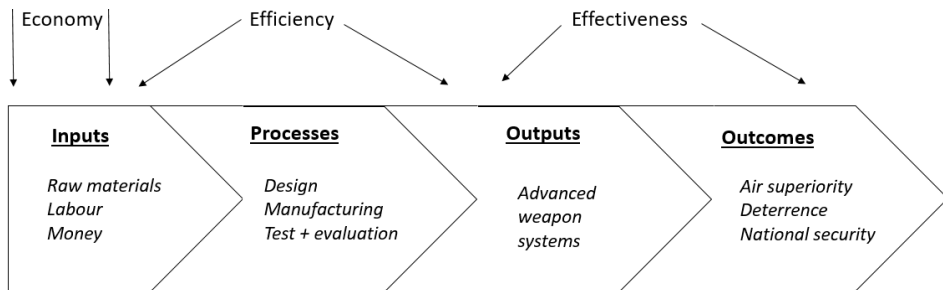
Source: Redrawn from *Louth* (2010, p. 108)

Indeed, in a comparative study of cost and performance changes between the UK and US major defence acquisition programmes based on government audit data from 2013 and 2014, *Bellais & Droff* (2017) conclude that despite the implementation of successive defence acquisition reforms (e.g. Smart Acquisition in the UK and Adaptive Acquisition in the US), there has been no perceptible change since the 1990s and defence programmes are still sensible to under-performances and delays. This trend is confirmed by a 2020 GAO report on defence acquisitions which highlights that major defence acquisition programmes have accumulated over $628 billion (or 54 per cent) in total cost growth since the program started and that over the same time period, the time required to deliver initial capabilities has increased by 30 per cent, resulting in an average delay of more than two years (*GAO*, 2020b, p. 2).

The problem is that the Linear Transformation Model draws on a simple cause-effect rationale which does not take into account the wider contextual factors inherent to defence acquisition. It is essentially based on a one-dimensional approach in which a desired outcome (e.g. national security) determines the requirements for the outputs (e.g. tanks, aircraft, missiles) which in turn determine the requirements for inputs (e.g. raw materials, manpower) and processes (e.g. design, R&D, manufacturing). As such, it is unable to address more complex questions such as the desirability of one weapon system over another or the value of national security.

In terms of the former, key technologies which are at the heart of major platform systems (e.g. combat aircraft, battleships and tanks) have reached their maturity and incremental performance improvements come with complex solutions, technological uncertainties and rising challenges during the development stage (*Davies et al.*, 2012). The F-35 combat aircraft provides a good example of how the choice of a defence output (in this case a fifth-generation combat aircraft) which is supportive of a certain outcome (in this case air superiority) has become a hot subject of debate, not least because of its cost and schedule escalation (*CRS*, 2022; *Petrelli*, 2020).

With respect to the latter, national security, it is worth recalling that national security is generally considered a public good. As such, it carries not only military value but also significant social value, particularly in relation to its opportunity cost, that is the value given up by engaging means into defence, relative to engaging them in health or education (*Markowski et al., 2010*, p. 14). The point is that national security leaves significant room for interpretation.

Overall, the military and social value of defence outcomes and their uncertain nature make it difficult to work out the derived demand for defence inputs and the associated industry capabilities.

Wicked problems do not have an exhaustively describable set of potential solutions, nor is there a well-described set of permissible operations that may be incorporated into the plan

Moreover, defence outcomes comprise two subsets, one related to deterrence and the other related to the actual deployment of force (*Markowski et al.*, 2010, p.15). It is the latter that is the most problematic as it implies being prepared for multiple and unforeseeable military contingencies or threat scenarios. For example, from the Cold War to the Russo-Ukrainian War, the risk of state-on-state conflict had diminished, whilst the likelihood of conflict involving non-state and failed state actors employing asymmetric tactics such as economic, cyber and proxy actions rather than direct military confrontation had increased (*Bishop*, 2017, p. 58).

In order to respond to potential threat scenarios, the defence must generate appropriate military capabilities (outputs). Knowing what military capabilities are required calls not only for knowledge of a wide range of scenarios but also for informed judgement and decision-making. Indeed, similarly to *Rittel & Webber's* (1973, p. 164) planning-type problems, in which a host of potential solutions arises and in which "the set of feasible plans of action" relies on realistic judgement, the capability to apprise exotic ideas and on the amount of trust and credibility between planner and clientele", in defence acquisition, "the set of a feasible plan of action" requires balancing the likelihood of the threat, the impact of the desired outcome, the effect of the planned output and the costs of the engaged inputs and process.

The difficulty however is that decisions need to be taken on the basis of imperfect information and are thus doomed to interpretation and value judgment. The lack of (reliable) information and data is a result of how the defence is organised and managed in practice: Since only a few threat scenarios will ever materialise, what states actually provide through defence acquisition is a contingent capability, that is a capability that has the potential to be used if certain contingencies occur, but which will otherwise be visible only in the context of exercises and simulations (*Markowski et al.*, 2010, p. 17). On a positive note, exercises and simulations have the potential to enhance learning about how military assets perform in controlled experiments. On the negative side though, exercise and simulations lack the true dynamics of the real battlefield with their informational asymmetries and rapid product and process innovation by the combatants. In brief, contingent military capabilities cannot be directly measured in peacetime and rely on interpretation and judgment (*Markowski et al.*, 2010, p. 17).

Every wicked problem can be considered to be a symptom of another problem

A further difficulty in decision-making in defence acquisition stems from the unequal distribution of information between the buyer and the seller (*Hartley and Belin*, 2020). This is particularly relevant in the context of innovation and new technologies, in which military suppliers tend to have a competitive advantage (*Porter*, 1985) over their buyers (nation-states). In order to better understand this situation, a look into defence acquisition history and its evolution since World War II is necessary.

Over many decades, states have been focused on leading technology development and many technological and material innovations have come from defence R&D and have subsequently been commercialised for general application (*Neal*, 2017, p. 160). However, this is no longer the case. With the introduction of the global neoliberal agenda and the subsequent application of the New Public Management framework to defence acquisition, many hitherto state-owned military tasks and services have been outsourced and privatised (*Ekström & Dorn*, 2014). Today, the prime sources of innovation come from the commercial sector and increasingly states look to industry for possible technologies and materials that they can utilise. To add a further layer of difficulty, the majority of new products and innovative solutions do not come from large defence companies but rather from the defence sector small to medium size enterprises (SMEs) or indeed from non-defence industries (*Hartley*, 2018, *Neal,* 2017).

The point is that knowledge and know-how are no longer state-owned but contained within different professional networks and organisational cultures. Following *McAvoy* (2017, p. 223), state actors need to liberate themselves from their embedded interpretations of social reality and their dominant institutional logics (e.g. mind-sets like "the way things are done around here") in order to harvest and decode the new forms of knowledge and know-how. The reason is that institutional logic is endemic to a particular institutional order and involves an agent's interpretation of social reality within the environmental context in which the institutional logic is translated (*Friedland & Alford*, 1991).

From such a perspective, the neoliberal policy reforms of defence acquisition (i.e. competition as the default mechanism and risk transfer to the private sector) only address a symptom of the problem (i.e. escalating costs of modern weapon systems and shrinking defence budgets) and not its root cause: an obsolete institutional culture that needs to develop new skill sets and competencies to match the changing environment of defence acquisition. In *Moore's* (2017, p. 256) words: "In order to successfully assimilate and integrate all of the complexities and complications of the defence acquisition context, those involved must respond to stimuli from inside and outside of the defence acquisition environment."

While for *Moore* (2017, p. 256), the development of an own body of knowledge through practice and experiential learning (*Kolb*, 1984) is at the centre of the problem, for others, the lack of practical knowledge is only a symptom of a higher problem, namely the lack of a theoretical knowledge base. For example, *Burgess* (2017, p. 2) argues that defence acquisition should have not only a unique body of knowledge, but also its own distinct theory and that a combination of practical know-how and theoretical know-why should be applied. For him, Western neoliberal reform agendas

have fundamentally altered the roles, systems and processes of defence acquisition, so that a far more comprehensive theory is required to effectively inform current and future practice requirements (*Burgess*, 2017, p. 2).

The existence of a discrepancy representing a wicked problem can be explained in numerous ways. The choice of explanation determines the nature of the problem's resolution

The theory-practice divide in defence acquisition confirms *Rittel & Webber's* (1973, p. 165) point that "the level at which a [wicked] problem is selected depends upon the self-confidence of the analyst and cannot be decided on logical grounds" and that "the higher the level of a [wicked] problem's formulation, the broader and more general it becomes and the more difficult it becomes to do something about it". Most importantly, it illustrates that the analyst's worldview is the strongest determining factor in explaining a discrepancy, and thus resolving a wicked problem (*Rittel & Webber's*, 1973, p. 166).

In *Moore's* (2017) worldview, decision-making in defence acquisition should be informed by professional judgement based on a balanced mix of professional, contextual and specialised knowledge. In particular, *Moore* (2017, p. 255) advocates a novel defence acquisition professionalism that builds on "wider, outside-the-box thinking, intuition, flair, innovation, diplomacy, the ability to work within a team to solve practical problems and above all to exercise judgement to gain optimum solutions for all stakeholders". *Moore's* (2017) position is backed by *Leefez* (2017a) who lobbies for a multi-theoretical perspective to investigate defence acquisition practices. For *Leefez* (2017a, p. 80), a narrow-based approach to management is reductive because defence acquisition is more than a matter of efficient allocation of resources and thus begs for a broad-based approach capable of including the social context in which defence acquisition programmes take place.

Wicked problems have no stopping rule

By contrast to solving a traditional science problem (e.g. mathematical equation), where it is easy to tell if and when the job has been done, solving a defence acquisition problem is not as clear cut. Although the Linear Transformation Model might suggest so (*Figure 3*), the preceding discussion has shown otherwise. Indeed, because threat scenarios are inherently contingent, their solutions (advanced weapon systems) are also contingent. This adds an important layer of uncertainty to defence acquisition: A state can never be too confident that its military capabilities are able to cover the next threat scenario, the reason being that the nature of actual and potential warfare continuously changes as a result of technological change and new developments in strategic thinking (*Markowski et al.*, 2010, p. 29). For example, in the Afghanistan and Iraq Wars, the US ground forces faced irregular warfare scenarios to which they were ill-prepared. Their vehicles were vulnerable to mine and improvised explosive device (IED) attacks and needed to be retrofitted with a mine-resistant ambush protection (MRAP) kit (*Feickert*, 2011). Since then, MRAP has become an important user requirement and is integrated into many vehicles from scratch.

In spite of the proliferation of irregular warfare scenarios (e.g. Mali, Democratic Republic of Congo), the recent Russian attack on Ukraine is a powerful reminder that the threat of interstate war (i.e. conventional warfare) cannot be ignored. Hence, states need dynamic capabilities (*Teece et al.*, 1997) to integrate, build, and reconfigure internal as well as external competencies to address the rapidly changing security environment (*Balakrishnan*, 2017, p. 274). In management theory, the ability to prepare for the "old" and "new" is known as organisational ambidexterity. *O'Reilly & Tushman* (*2013*, p. 324) define organisational ambidexterity as "the ability of an organisation to both explore and exploit" where exploiting refers to "competing in mature technologies and markets in which efficiency, control, and incremental improvements are prized", and exploring refers to "competing in new technologies and markets in which flexibility, autonomy, and experimentation is needed". Most importantly, *O'Reilly & Tushman* (2013, p. 324) see long-term firm survival as dependent on the ability to simultaneously pursue incremental and discontinuous innovation.

The arguments put forward by *O'Reilly & Tushman* (2013) hold true for defence and defence acquisition. In order to cover old and new security threats, states need to improve existing capabilities while at the same time exploring new ones. Defence acquisition is thus driven by two parameters: preparing the next generation of existing platforms to avoid any capability gap or loss of industrial capacities (exploring) and pushing the growth potential of existing technologies to maintain the technological edge vis-à-vis potential enemies (exploiting) (*Bellais & Droff*, 2017, p. 213).

Solutions to wicked problems are not true-or-false, but good-or-bad

Similarly to wicked planning-type problems, in which many parties are equally entitled to judge the solutions and none has the power to set formal decision rules to determine correctness (*Rittel & Webber*, 1973, p. 163), in defence acquisition, there are no independent judgment criteria. Depending on their level of knowledge, values, role and responsibilities, different stakeholders will assess threat scenarios differently and call for different solutions. For instance, a soldier on the battlefield whose life is at risk may judge the need for the latest battle tank technology differently than a four-star general at the Pentagon whose reputation is at stake or a politician in Washington whose primary focus is on winning the next elections.

In an attempt to address the judgment-assessment dilemma, *Snider* (2017, p. 199) proposes to change the role of the programme manager from a politically-neutral expert to an actor who has an appreciation for the needs and interests of other stakeholders as well as the conditions and circumstances of the acquisition environment. For *Snider* (2017, p. 199), the programme manager should act as a central and active catalyst in facilitating dialogue, relationships, and meaning creation among all participants. This would ultimately shift the focus from first-order learning and "doing things right" to second-order learning and "doing the right thing" and thus take into account the inherently wicked nature of defence acquisition (*Flood & Romm*, 1996).

Snider's (2017) call for more social value in defence acquisition is confirmed by *Lefeez* (2017b, 2014), who investigated the relationships between military leadership (État-major), the defence acquisition department (DGA) and the defence industry in France. *Lefeez* (2017b, 2014) highlights that the different groups expressed their

mistrust of one another and asked for more mutual confidence, pointing out that confidence was a central issue in the defence acquisition process. All things considered, *Lefeez* (2017b, 2014) concludes that military needs are not only determined by operational considerations, but also by social factors.

Every solution to a wicked problem is a "one-shot operation"; because there is no opportunity to learn by trial-and-error, every attempt counts significantly

Rittel & Webber (1973, p. 163) underscore that with wicked planning-type problems, every implemented solution is consequential and leaves traces that cannot be undone, as opposed to traditional science problems (e.g. mathematics), in which the problem solver can try various runs without penalty. The same logic holds true for defence acquisition. A bad strategic development and/or acquisition choice cannot only result in a higher number of casualties on the battlefield but ultimately put the national security of a nation at risk (*Markowski et al.*, 2010, p. 18). Moreover, considering the importance that nations attribute to their defence budgets (NATO nations spent in total 2.57 per cent of GDP on defence in 2022), defence programmes also carry significant economic weight (*NATO*, 2022).

In order to get a better understanding of the "economic traces" that defence acquisition leaves behind, it is necessary to take a closer look into the functioning of the defence sector. The defence sector functions as a combination of a monopsony and an oligopoly. A monopsony describes a market structure in which a single buyer (the nation-state) substantially controls the market as the major purchaser of goods and services offered by many sellers, whereas an oligopoly describes a market condition in which a market is dominated by a small number of large sellers (defence companies) (*Markowski*, 2010, p. 120).

The hybrid market structure of the defence sector has basically two origins. First, because the state has the monopoly of the force, it is the only legitimate defence buyer. This however has important consequences for the seller. In a market with a single buyer, business opportunities are rare, and a major contract may represent a "must-win" deal for a seller company, where it may be forced to lay off workers and diminish its capability, perhaps leave the sector, or even go into liquidation if it does not prevail (*Taylor*, 2017, p. 30). For example, Hunting Engineering opted to leave defence when it lost its role at the Atomic Weapons Establishment and Vosper Thorneycroft gave up competing for ship development work and sold its shipbuilding business to BAE Systems (*Taylor*, 2017, p. 25).

Second, diminishing budgets, growth in global competition and increasing exposure to open market practices led to the merger and consolidation of both the US and EU defence industries (*Uttley*, 2018, p682). Today, the US market is dominated by five major defence companies, namely Lockheed Martin, Northrop Grumman, Raytheon, Boeing and General Dynamics, and the EU market by four major defence companies, namely BAE Systems, Airbus, Thales and Leonardo (*SIPRI*, 2022).

Depending on their defence profile, states use different strategies to protect and/or boost their defence technological and industrial base (DTIB). For instance,

states with a comparatively large defence sector like the UK or the US tend to follow an "identify and exploit export markets" approach. Yet, exporting to third-world buyers has also left their DTIB vulnerable to the shifting buying power of those states which often are dependent on the price of raw materials and fluctuating defence spending (*Bishop*, 2017, p. 66). By contrast, states with a small DTIB like Norway and Turkey use defence imports as a catalyst to acquire technology, either through reverse engineering, licensing or co-production, amongst other options, to be able to move up the technological ladder, with the aim of eventually becoming self-reliant (*Balakrishnan*, 2017, p. 267). For instance, Turkey assembled the F-16 fighter under a US licence from 1984 until 1999. However, despite gains in aircraft and composite parts production technologies and know-how, the local value-added remained disappointingly low –only about 8–9 per cent of the value of an F-16 fighter (*Güvenç & Yanik*, 2012, p. 117).

In defence acquisition, the practice of using technology from a foreign supplier as an economic development tool is known as "offsets". Offsets and its sister principle "juste retour" (principle of fair industrial return) are popular tools, particularly when highly advanced technology is involved (see *Matthews*, 2014). Especially smaller military powers such as Belgium and the Netherlands rely on offsets for maximising domestic industrial benefits, not least because they lack the domestic capacity to develop large-scale defence programs (*de France et al.*, 2016).

However, the use of 'economically motivated' offsets remains controversial and has been outlawed under EU law (*Uttley*, 2018, p. 681). Indeed, following a 2012 Guidance Note on offsets from *Directorate General Internal Markets and Services*, the use of offset may only be justified by essential security interests of the state (Article 346 TFEU), whereas economic considerations exclude its use. In addition, no concrete evidence exists that general economic development goals are ever achieved via offsets (*Markowski & Hall*, 2014; *Brauer & Dune*, 2011. Unsurprisingly, offset practices and the "juste retour" principle have been exposed to sustained criticism and are seen by many as one of the main obstacles to the creation of a genuine European defence equipment market (*Calcara*, 2020; *Hartley*, 2020b).

The planner has no right to be wrong

By contrast to *Popper's* (1961) principle of science, in which solutions to problems are only hypotheses offered for refutation and thus part of the scientific truth-finding process, in defence acquisition, every developed solution (output) follows a particular aim (outcome) and has thus "no right to be wrong". Indeed, as mentioned elsewhere in the article, a bad strategic development and/or acquisition choice can have immense detrimental consequences for a nation, not only on the battlefield but also in economic terms. In this respect, programme managers are liable for the consequences of the actions they generate.

The Dreadnought battleship experience is a case in point. At the end of the 19th century, thick armour plating led to a revolution in warship design and the development of the Dreadnought battleship class (*Louth*, 2017, p. 41). At the time, it was believed that nothing could counter a fleet of such strength. However, the first major fleet-on-fleet clash of the First World War at Jutland in 1916 showed that

firepower anticipated from Dreadnought-derived ships was neither superbly accurate nor decisive. Moreover, admirals tended to be reluctant to risk their Dreadnought ships in combat as they were disproportionately valuable and strategically important, not least due to their enormous acquisition costs (*Louth*, 2017, p. 42).

A similar discussion currently revolves around the US aircraft carrier strategy. For many, the acquisition costs of an aircraft carrier do not match its strategic battle value (*Cochran*, 2018; *Rubel*, 2011). The main criticism is that aircraft carriers have become vulnerable to novel weapon systems such as loitering munition. In particular, it is argued that a swarm of attacking drones could inflict serious damage to an aircraft carrier. While defensive measures are able to cope with cruise missile attacks, their effectiveness is less clear when it comes to repelling loitering munition (e.g. drone swarm attack). Furthermore, the resources and capabilities needed to produce and operate a major platform system such as an aircraft carrier are in stark contrast to the resources and capabilities needed to acquire and deploy loitering munition.

Again, all comes down to good judgement and decision-making, or as *Moore* (2017) puts it, to be an "intelligent customer". For *Moore* (2017, p. 259), good (enhanced) decision-making in defence acquisition is the result of professional judgment based upon a balanced mix of knowledge. Most importantly, he sees training and education as key factors in the process. He argues that training builds "process knowledge" and that education builds "propositional knowledge", and that both are filtered through a perspective of "personal knowledge" to inform a "balanced mix of knowledge" which ultimately builds the "professional knowledge base" (*Moore* 2017, p. 259) (*Figure 4*).

Moore's concept of the "intelligent customer" is reminiscent of the Swedish experience. In Sweden, the "competent and demanding customer" (that is the Swedish Armed Forces) has not only contributed to the evolution of the Swedish (military) industry, but also actively supported the development of modern weapon systems, the latest being the Gripen combat aircraft. (see *Eliasson*, 2017, 2011, 2010, 2000, 1990).

Figure 4: The development process of a professional knowledge base in defence acquisition
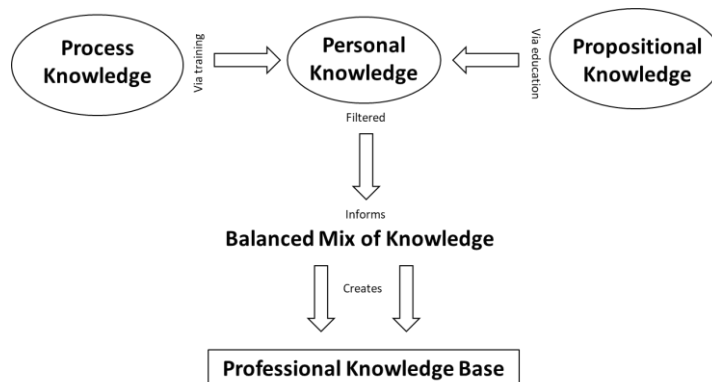
Source: Redrawn from *Moore* (2017, p. 259)

CONCLUSION

Exploring defence acquisition through the lens of *Rittel & Webber's* (1973) wicked problem has shown that defence acquisition is best understood as an open system with dynamic causal web structures and uncertain intervention points, and not as a closed system with fixed boundaries and predictable cause-effect relationships. All eight investigated properties of a wicked problem have explanatory power and empirical value.

In particular, the analysis has pointed out that the contested value of defence outcomes combined with the unforeseeable character of threat scenarios contributes to the contingent nature of military capabilities. This creates an important lack of (reliable) information and knowledge, which ultimately leads to interpretation and judgment in defence acquisition.

Moreover, the analysis has shown that the US and UK defence acquisition frameworks fail to cope with the changing nature of defence acquisition. The reason is that the Linear Transformation Model, their structural base, relies on a straightforward "input-process-output-outcome" logic which is unable to account for the complex networked structure and connected workings inherent to defence acquisition.

While for some authors like *Moore* (2017), *Lefeez* (2017a, 2017b, 2014) and *Snider* (2017), the failures of the neoliberal policies and their reform agendas are best explained by a "problem of practice" (that is the need for a better practical and experiential understanding of the institutional logics that shape the defence acquisition process), for others such as *Burgess* (2017), the core issue is not a problem of practice but rather a "problem of theory" (that is the need for defence acquisition practice to be underpinned by a well-developed defence acquisition theory or meta-theory).

As an actor who has been working in defence acquisition for many years, the author supports both positions. On the one hand, it is true that the current defence acquisition practices contain substantial knowledge gaps and are driven by the "tyranny of the urgent" (*Burgess*, 2017) with immediate short-term outputs dominating over long-term strategic outcomes. Most importantly, if not addressed in a structural way (i.e. by developing a meta-theory that accounts not only for the technical processes but also for its hidden institutional logics), the existing knowledge gaps are likely to grow and amplify the systemic deficits in defence acquisition. On the other hand, the networked nature of defence acquisition begs for deeper practical knowledge of the relationship between structure and agency and how new institutional logics can be implemented at the individual level, that is how actors access the cultural resources (i.e. values, norms and beliefs) embedded within their social and professional networks to act as agents of change.

Further research on the theory-practice divide is necessary in order to transform the institutional culture of defence acquisition and remedy its systemic shortcomings. Considering the multiple reforms that defence acquisition has undergone since the end of the Cold War, it can be said that there is a genuine will to change defence acquisition for the better. By adopting a new perspective to the table, namely that of

defence acquisition as a wicked problem, the author hopes to make a positive contribution to defence acquisition.

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K-means Cluster Analysis of Hourly Measured Power Demand in the District Heating System in Kaposvár – Putting Theoretical Figures into Practical Use

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ABSTRACT

In this paper the actual cluster analysis is performed to identify clusters within the Kaposvár district heating system. The data were not measured directly in households but at heat transfer stations. The smart meters were installed at the heat transfer stations for several reasons: to measure and control the required supply temperature and also to find leakages quicker and easier. K-means method was used and four different clusters were identified, which were the following: high demand of heating with long operating hours, low demand of heating with long operating hours and low demand of heating with short operating hours. The details and the determined values will be used for further research. First steps towards identifying new heat sources have also been identified.
Keywords: smart meter data analysis, carbon emissions reduction, waste heat utilization, energy efficiency, sustainable energy
JEL codes: C38, L97

INTRODUCTION

Faced with the challenges of climate change and the need to ensure sustainable economic growth and social cohesion, Europe must achieve a genuine energy revolution to reverse current unsustainable trends and meet ambitious policy expectations. To meet this challenge, district heating (and cooling) systems must become more efficient, smarter and cheaper. "In contrast to the analysis of electricity smart meter data, little research has been published on district heating (smart) meter data" (*Tureczek et al.*, 2019)

District heating (also known as heat networks or teleheating) is a system that distributes heat generated at a central location through an insulated pipe system to meet residential and commercial heating needs such as space heating and water heating. The heat is often generated from a combined heat and power plant burning fossil fuels or biomass, but also from heat-only boiler stations, geothermal heating, heat pumps and central solar heating. Waste heat from factories and nuclear power electricity generation is also used and is common. District heating plants can provide higher efficiency and better pollution reduction than local boilers. Some research has shown that district heating with combined heat and power (CHP) is the cheapest way

to cut carbon emissions, and has one of the lowest carbon footprints of all fossil generation plants. (*Andrews*, 2009).

The first aim of this paper is to analyse potential clusters of the measured heat demand data to provide an insight into possible key points for further discussions. The clusters found will be the starting points for additional measures to be taken in the future, which may include not only recommendations to homeowners for insulation, but also possible changes in the tariffs and charges to be paid. The tariff structure can play a key role in encouraging the adoption of environmentally friendly behaviour – lower demand would mean lower supply temperatures, less gas or biomass and – for the end user – fewer static parts in the bills. These issues are not discussed in this paper, they should be investigated in further research.

The second aim is to provide some additional ideas on smart energy use and energy production, in particular in the field of district heat production. The calculation of the clusters alone does not provide too much practical added value but the reduction of CO_2 emission used for heat production would be a sustainable result that can be based on the calculated figures. The reduction in heat demand and consumption for some individual users is highly dependent on general environmental factors such as external temperature, weather conditions and also political measures.
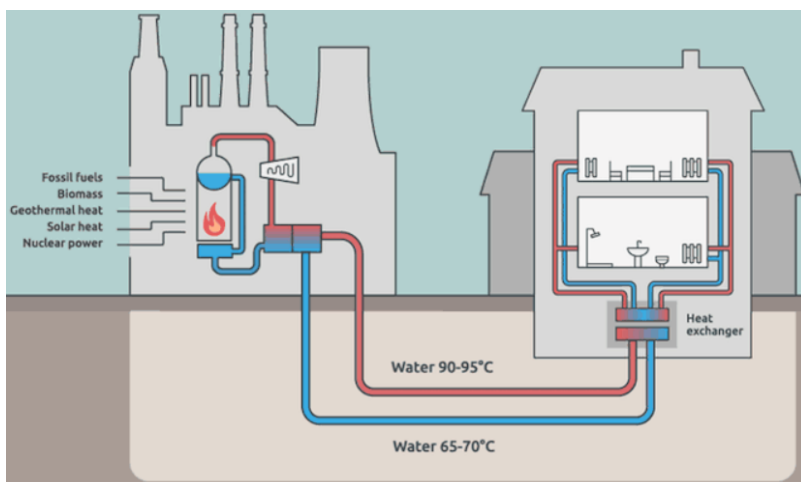
District heating (dh)

District heating is the supply of heat to buildings through a heating network that transports thermal energy. Water is heated using a power plant, solar thermal or geothermal installation or a large heat pump and then piped into an insulated (and usually buried) network of of pipes, directly to the buildings connected to the system. The water then flows through a transfer station to the building's own heat distribution system, which provides the heating energy and hot water supply. Once the water cools down, it flows back to the original heat source and the cycle starts all over again. In other words, buildings with district heating can do without their own heating systems and chimneys. A visual image of the above description can be seen in *Figure 1*. District heating systems are supply systems that consist of district heating plants, pressure and volume maintenance plants, water treatment plants, district heat transportation systems, and distribution networks, as well as customer transfer stations. As such a system must always balance district heating output and production, an additional heating center is responsible for the efficient control of the system.

District heating is therefore a valuable product that is predominantly produced by combined heat and power production (i.e., combined production of electricity and heat). The supply of the district heating is as simple as this: The heat from the district heating system is transported to the customer via a pipeline system using a transport medium (usually hot water). The heat is transferred to the building via a domestic transfer station. The cooled water is then returned from the building to the network.

District heating not only reduces the demand for resources – it also protects the climate. The requirements of the Net Zero Emissions by 2050 Scenario call for the combined share of renewable sources and electricity in global district heat supplies to increase from 8% of today to about 35% by the current decade, contributing to a reduction of carbon emissions from heat generation by more than a third. (*IEA*, 2021)

Figure 1: How the district heating system works

Source: https://upload.wikimedia.org/wikipedia/commons/0/0d/District_heating.gif

In 2021, the number of apartments and homes using district heating in Kaposvár was 6 900, which represents 30% of the city's dwellings, and provides heating for 305 other heated buildings. This is an exceptional and outstanding proportion in Hungary (*Bánkuti & Zanatyné Uitz*, 2021).

The continuous drive to improve the carbon footprint of heat production and contribute to sustainability can be seen in several areas. An example is the installation of a biogas plant in 2007. It not only reduced the dependency on natural gas and ensured the additional supply of methane gas, but it also contributed to the survival of the AGRANA subsidiary Magyar Cukor Zrt. (Hungarian Sugar Private Limited Company, hereinafter referred to as "the sugar factory"), with a capital investment of HUF 1.7 billion (about EUR 6.8 million).

In 2015, the city of Kaposvár completely replaced its outdated diesel-powered city buses with 40 compressed natural gas (CNG) vehicles, which significantly improved the city's air quality. The sugar factory power plant - with its two extremely large fermenters of a useful volume of 12000 m^3 – is still unique in the European sugar industry. Local professionals found that the production reached the value of 140.000 m^3 with an average methane content of 53% (*Csima & Szendefy*, 2009).

In 2019, the natural gas-fired heating plant operated with an installed thermal capacity of 51.7 MWt, and with a combined electricity generation of 1.9 MWt. The electrical capacity of the installed gas-fired engine was 1.35MWe. These technical facts show the intention to strive for more sustainable production throughout the process.

Literature review

The literature which clustering method should be based on was reviewed in details beforehand and will be published within the Ohio Journal of Science (*Radtke*, 2022). The conclusion shall be summarised below for a better comprehension of the subject.

Conclusion

The reviewed literature on clustering, mainly describe the methodology of clustering by K-means. The K-means algorithm is considered to be the best known and most frequently used clustering method, which divides the dataset into k clusters by minimizing the sum of all distances to the respective cluster centers (*Ramos et al.*, 2015). The use of K-means clustering algorithm is well covered in the literature and can serve as a basis for further tests on models and other clustering methods. Several alternative methods have been described and tested, but no common ground for additional clustering methods was found in the literature reviewed. Each researcher who used an alternative approach only compared results using K-means. The main differences between the articles are the database, some very small, and the data preparation. Each article used its own set of data, some very small, ranging from only two apartments up to over 500 metering points within district heating networks, while for similar electricity measurements nearly 15.000 measuring points were analysed.

However, the literature reviewed observed additional differences in those who performed a comparative analysis between electricity and heating measures: the influencing factors indicate that the outdoor temperature has a significant effect, including on the area of living. Data gathered in Genoa showed fewer peaks and less significant differences than the evaluation of data collected in Northern Europe (GB, Sweden). The conclusion was fairly similar. The most influential factors affecting volatile consumption were temperature and the type of building in which the measures were taken. The results showed the effect of modern insulation compared to non-insulated insulation. However, all researchers adjusted the data, which indicated that consumption remained stable over the period analyzed.

The use of K-means clustering algorithm is mandatory and should not be omitted. All other clustering approach should be compared to the results of the K-means method. According to the literature reviewed, the K-means algorithm (which was used in several other methods such as nbclust (GMM) showed similar results to all other methodologies used. Outliers should be respected and accepted – but this is a general rule when using K-means algorithm. According to the literature reviewed, the best documented approach is K-means; only one article used other algorithms, while two thirds of the articles contained findings and results for K-means.

Checking the geographical origin of the data, there is no coverage of Eastern European countries. Even before the functional limitation on heat loads and patterns or even district heating, no observed data were produced using data from Eastern Europe. This may be due to the lack of interest in research in or the lack of researchers' interest. But the lack of available data may also be a reason for the lack of research. A fourth explanation could be the geographical boundedness of publishing journals. Here again seems to be a research gap.

As some practical ideas should also be developed, an additional literature review on waste heat utilization was carried out. *Fang et al.*, (2013) provided a detailed investigation into the thermal grade and quantity of low-grade waste heat sources in Chifeng, China. Waste heat recovery for productive use can reduce CO_2 emissions as well as reduce the use of fossil fuels and water dissipation. The authors proposed a holistic approach to an integrated and efficient utilization of low-grade industrial waste heat.

Woolley et al., (2018) describe a framework for waste heat energy recovery that provides a four-step methodology for manufacturers. Their article provides a recommendation for facilities to assess production activities, analyzing the compatibility of waste heat sources in terms of exergy balance and temporal availability. They did this by selecting appropriate heat recovery technologies and decision support based on economic benefits. Their work was based in the UK and their research observed a lack of data. Finally, they used data that consisted of original data from a commercial company and published literature which they referred to where the information they wanted was not available from the company.

The potential for waste heat recovery data center was analyzed by *Wahlroos et al.,* (2018). They used Northern European countries, in particular Finland, as the data center operators of Finland were planning to reuse waste heat in district heating. They attempted to overcome the lack of transparency of the business models between the district heating network operator and data center operator by a life cycle assessment analysis. The authors proposed a systematic process of change to succeed in changing the priority of waste heat utilization in the data center and district heating market.

Knudsen et al., (2021) explored the key technology of thermal energy storage. It is used to enable the utilization of industrial waste heat in district heating. The authors tried to solve the problem of sizing these storages in heating plants using a variable waste-heat source. They developed a model that combined dynamic simulation and a model predictive control approach. This takes into account the dynamics and optimal control of the heating plant using a thermal energy storage. Their case study was carried out in Norway.

One of the most influential papers was written by (*Köfinger et al.,* 2018), who examined different technical and infrastructural options, and conducted economic analyses to better implement these options. Their study was based on data from the city of Linz (Austria). The existing industry showed significant unused waste heat potentials that could be integrated into the existing urban district heating system but no additional seasonal storage was available. This was due to a competition with an existing waste incineration plant in Linz. The authors found that by operating the seasonal storage strategically, the number of charging cycles could be increased, thereby the revenues of the system can significantly be increased. A combined utilization of the seasonal storage system would allow waste heat to be transferred from the summer to the winter period and it can be used as a short-term buffer.

Summarizing the reviewed literature in regard to the source of data or place of research included again a lack of easter Europa coverage. A number of studies were reviewed, particularly with regard to the source of data – no English-language studies investigating Hungary, Romania or Slovakia, or even other eastern European countries were found. China, Western and Northern Europe were investigated mainly because of their natural environment (long winters with a long heating period) and their state of industrialisation. However, the research of using alternative heat sources to replace fossil fuels is essential to sustainable and low-carbon heat supply and it is therefore a key element in demonstrating the energy systems of the future.

MATERIAL AND METHODS

As found and described in the literature review, the clustering approach should be taken using the K-means method. K-means clustering is a method of vector quantization, originally from signal processing, which aims to divide the n observations into k clusters, where each observation belongs to the cluster with the nearest mean (cluster centers or cluster centroid), serving as the prototype of the cluster. This results in a partitioning of the data space into Voronoi cells. K-means clustering minimizes intra-cluster variances (squared Euclidean distances), but not regular Euclidean distances, which would be a more difficult Weber problem: the mean optimizes squared errors, whereas only the geometric median minimizes Euclidean distances. Better Euclidean solutions can be found, for example, using k-medians and k-medoids (*MacQueen*, 1967). This is a well-known approach to clustering data (*Jain*, 2010).

The most common algorithm uses an iterative refinement technique. Due to its ubiquity, it is often called "the K-means algorithm"; it is referred to as native K-means:

Given an initial set of k means $m_1^{(1)}, \dots, m_k^{(1)}$ (see below), the algorithm proceeds by alternating between two steps:

Assignment step: Assign each observation to the cluster with the nearest mean: that with the least squared Euclidean distance[1] (this means partitioning the observations according to the Voronoi diagram generated by the means).

$$S_i^{(t)} = \{x_p : \left\| x_p - m_i^{(t)} \right\|^2 \leq \left\| x_p - m_j^{(t)} \right\|^2 \ \forall j, 1 \leq j \leq k\} \tag{1}$$

where each is assigned to exactly one $S_{(t)}$, even if it could be assigned to two or more of them. $S^{(t)}$ are sets $S = \{S_1, S_2, ..., S_k\}$.

Update step: compute recalculated means (centroids) for the observations assigned to each cluster:

$$m_i^{t+1} = \frac{1}{\left| S_i^{(t)} \right|} \sum_{x_j \in S_i^{(t)}} x_j \tag{2}$$

The algorithm converges when the assignments no longer change. The algorithm is not guaranteed to find the optimum. The algorithm is often presented as assigning objects to the nearest cluster by distance. Using a different distance function other than (squared) Euclidean distance may prevent the algorithm from converging. Various modifications of K-means such as spherical K-means and k-medoids have been proposed to allow using other distance measures (*MacKay*, 2003).

The data was provided by the district heating company of Kaposvár. The data used consists of around 300 devices, measured hourly for 365 days. With a set of 3.3 million measurements the analysis can no longer be done on a simple PC. But the

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[1] In mathematics, the Euclidean distance between two points in Euclidean space is the length of a line segment between the two points. It can be calculated from the Cartesian coordinates of the points using the Pythagorean theorem, therefore occasionally being called the Pythagorean distance. These names come from the ancient Greek mathematicians Euclid and Pythagoras, although Euclid did not represent distances as numbers, and the connection from the Pythagorean theorem to distance calculation was not made until the 18th century.

research has proved our assumptions. Similar results can be achieved with random samples of 10.000 data. As only two dimensions have been available for public use - the result may still reveal 4 clusters in a 2-dimensional space in the future. No district heating company is likely to want high demand with short operating hours. Of course, the method used to analyze the data included standards such as removing unmeasured sets, controlling for data bias and transforming the data.

Data description and preliminary steps

After the initial analysis, the data was converted from the given SQL Server format into a STATA readable format. The first step was to use STATA to convert the date and time as well as the measured demand (P1) into computerized format. But subsequent steps were done using R Script, as the library and documentation were more easily accessible, and the R Script allowed computerized output. In addition, the file 'measures_corr.dta' calculated by STATA could be converted into a format readable by R Script. The full script calculated with R Script can be found in the attachment to this work.

Data

The first step to get a first impression (*Figure 2*) was to show the basic statistics for the whole dataset.

Figure 2: Description of the unprocessed dataset

```
Data description:
obs:     3,332,901
vars:    6                               24 Nov 2021 21:31

              storage    display    value
variable name    type      format    label      variable label
cons_id          long      %12.0g               Cons_id
Dat_Ro           str19     %19s                 Dat_Ro
Op_hrs           int       %8.0g                Op_hrs
p1               str15     %15s                 P1
P1_numeric       float     %9.0g                P1
datetime         double    %tc

Summary:
     Variable |       Obs         Mean    Std. Dev.         Min         Max
-------------+-----------------------------------------------------------
      cons_id |   3332901     200140.3    43002.18      110101      241548
       dat_ro |         0
       op_hrs |   3332752     16973.64    6312.677           0       28597
           p1 |         0
   P1_numeric |   3332748      3403154    2.35e+09       -97.9    1.62e+12
-------------+-----------------------------------------------------------
     datetime |   3332901     1.94e+12    9.90e+09    1.92e+12    1.95e+12
```

The variable cons_id describes the unique device ID, P1 and P1_numeric which show the measured consumption. Op_hrs is the parameter for the operating hours, date and time, which has already been converted to date and time values stored in dat_ro. The values of P1 and dat_ro were given as string values, which cannot be used for further analysis and had to be converted in the very first step.

By performing data cleaning, outlier handling and Winsorizing, the following results were obtained:

- Detecting unique devices: 312
- Rounding time to full hours and identifying unique moments: 9953
- Determining minimal date und maximum date: Min: 2020-10-01 01:00; Max 2021-11-21 00:00

The dataset contains more than 365 dates with measurements; therefore, the set contains more than 365 days * 24 hours unique data. 288310 duplicate rows have been removed. The next task has been to cross-reference the unique dates and IDs to complete the data frame: 60745 Date/ID Combinations are missing and are filled in with NA in the cross-referenced data table. In addition, negative values and zero values had to be set to NA. The data contain such values which fluctuate since the smart device occasionally started to measure late, or it had to be calibrated later, it was defective or simply measured wrong values due to environmental situations.

After adjusting outliers to the 95% percentile - metric statistics for non-factor features (*Table 1*).

Table 1: Percentile-metric statistics (computed by R, own representation)

Variable/measure	vars	n	mean	sd	median	trimmed
P1	1	3044437	16807.51	6057.13	17423.0	16948.06
Operating hours	2	1795745	19.24	44531	16.2	17.51

| Variable/measure	min	max	range	skew	kurtosis	se
P1	5583.0	26840.0	21257.0	-0.20	-0.88	3.47
Operating hours	4.4	51.3	46.9	1.16	0.73	0.01

The *mean* and *sd* values of both variables are saved for later re-transformation of cluster centers. Furthermore, the distribution of these features is shown in histograms (*Figure 3* and *Figure 4*).

**Figure 3: Distribution of P1 and operating hours untransformed**
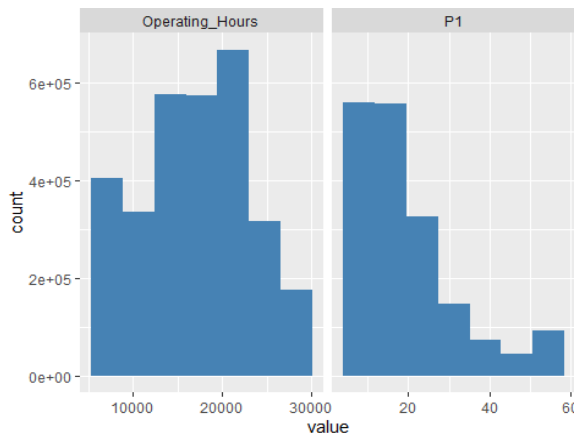
P1 heavily skewed and is therefore log-transformed in the next steps.

Figure 4: Distribution of operating hours and P1 after transformation
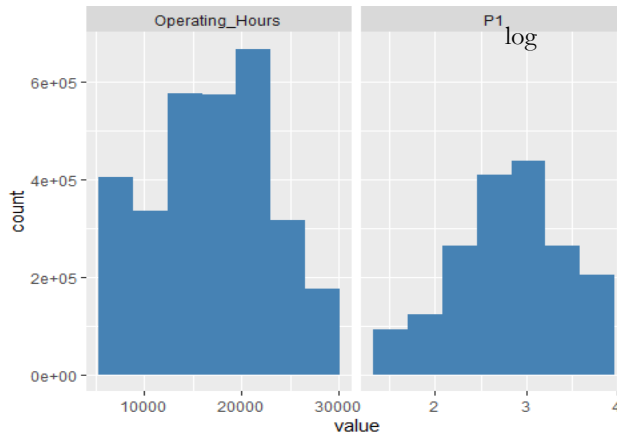
The P1 has become normal by now and can be used for modelling. In addition, the column has been renamed to logP1 for easier access and reading. The boxplot (*Figure* 5) also shows the normal distribution of the values used now.

Figure 5: Boxplot of operation hours and transformed P1
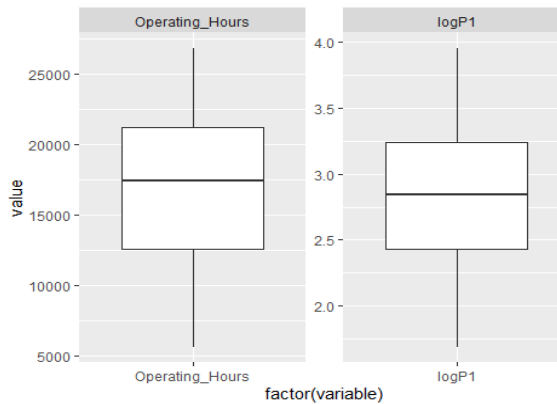
Finally, data preparation was almost complete. The last steps included the removal of the lines with missing values (already marked via NA) and melting the data.

RESULTS AND DISCUSSION

Sampling is required using the seed (by setting the seed for subsampling the same output at multiple runs was forced) – a sample of 10 000 values was used for subsampling df to n rows. Sampling was necessary to obtain reproducible results. The initial dataset could not be managed on a PowerBook workstation with a 6-core, 12-thread Xeon CPU at 2.7 GHz and 64 GB RAM. Clustering was performed using a virtual server cluster with 8 CPUs and 1024 GB RAM – but the system was not

available after an initial run. Therefore, we used the sub-sampling approach. The results between the full dataset and sampled dataset are shown and compared below.

To test and adjust the algorithm, a random number of k = 5 was initially used. The detailed data distribution was removed of the script below, only the sum of square was kept for later comparison.

The number of k has not been easy to identify so far, and in addition to the elbow method (*Figure 6*), gap statistics (*Figure 7*) must be used:

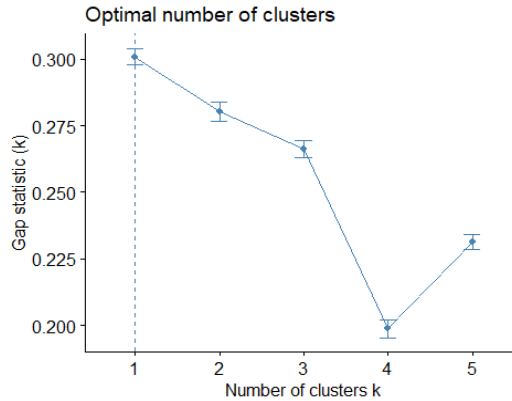## Figure 6: Elbow method for finding optimal k
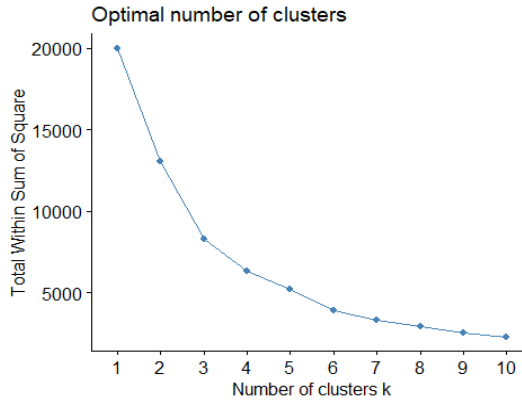
Figure 7: Optimal number of k using the gap statistics

The optimal value of k was calculated and is shown to be 4. So, in the next steps, clustering was performed using k = 4. This indicates that there are 4 clusters – the same result was obtained with the full data set. In term of the number of clusters, no difference was found between the sampled data and the full data set.

To evaluate the results, the cluster centers had to be reconfigured. The value of the log-transformed demand alone is not sufficient, it does not allow the evaluation of the identified clusters. The cluster centers can be easily determined by using the

appropriate command. However, the previously calculated standard deviation and mean values are needed for the re-transformed centres.

$$RC_k = CV * \sigma + \mu \tag{3}$$

RC_k is the retransformed center value of each cluster k, CV is the value of the center as determined by the K-means algorithm, σ is the standard deviation and μ is the mean. The calculated center values (*Table 2*) can be determined using R.

Table 2: cluster centres (calculated by R, own representation)

cluster	Operating_Hours	logP1
1	-0.5165050	0.9126801
2	1.0258957	0.4999305
3	0.7613733	-0.9752235
4	-1.0512699	-0.6988077

The values for standard deviation and mean have already been calculated within the metric statistics and now the formula is used form the calculation of the P1 values which have already been converted into to logarithmic value, the calculation had to be reversed using the exponential function.

$\mu_{OH} = 16807.51 \ \mu_{P1} = 19.24387 \ \sigma_{OH} = 6057.133 \ \sigma_{P1} = 12.21368$

Comparison between sampled value and complete dataset

Although the sampled data (*Figure 8*) show different colors for the clusters than for the full set of data (*Figure 9*), both have revealed 4 clusters, and clusters are visually located within the same area and close to each other. The above figure is included to demonstrate that the sampled result is very close to the result of the full dataset.

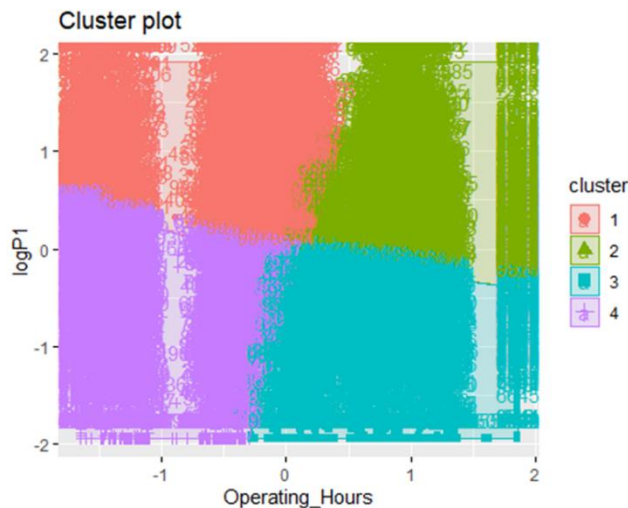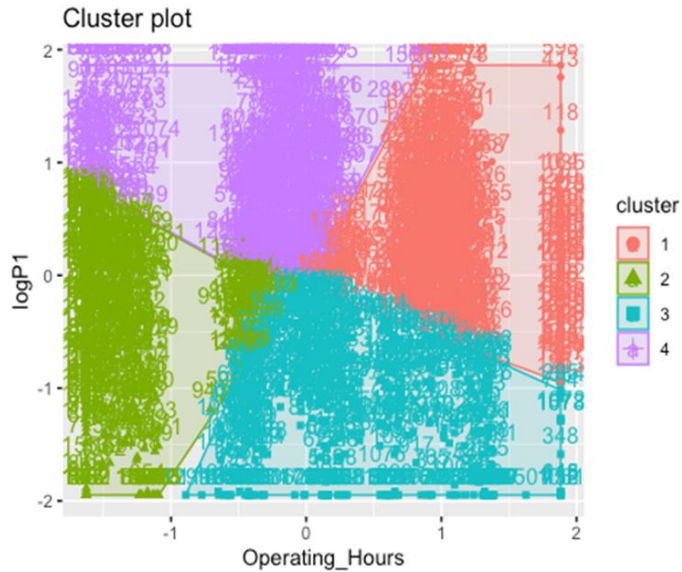**Figure 8: Sampled data set result of K-means analysis**

Figure 9: Result of K-means full data set analysis

The *Table 3* shows the clusters for easy comparison. Cluster 4 of the full set is set in comparison with cluster 1 of the sampled set, cluster 1 of the full set and cluster 2 of the sampled set represent the same cluster, cluster 3 is retained for the full set and the sampled set, and cluster 4 of the sampled set is cluster 2 of the full set.

Table 3: final results of transferred cluster values

Sampled data set			Full data set		
Cluster	Operating hours	P1	Cluster	Operating hours	P1
1	13678.97	37.45434	4	14264.07	40.21686
2	23021.50	27.16575	1	22963.40	24.17497
3	21419.25	11.63607	3	18798.65	10.98849
4	10439.83	13.10257	2	8609.02	15.10806

Without transformation, the data cannot not be used for further analysis. As the hardware demands for the entire data set were huge it is recommended to use a subset. Further tests were carried out with sampled data containing more than 10000 data points, but these showed no new results. The number of clusters and the area of the cluster remained the same. For the data provided, a total of four clusters were identified. One cluster represents rd. 25% of each measured value. The four identified clusters could be used for further analysis or as a basis for a new billing mechanism.

SUMMARY AND CONCLUSION

Of course, further details would need to be analyzed before any action could be taken to use the results discovered above. Such actions could be an adjustment of tariffs or

even the separation of individual buildings. In particular, anonymised data in quartiles should be reviewed. Since heat transfer stations were provided and measured, the houses behind these transfer stations should be identified. In case of the hospital, where higher demand is expected throughout the year – different measurements should be taken than for any single-family house or multi-tenanted building.

In summary, the results are as follows:

- K-means clustering on big data requires high performing hardware;
- Data sampling reveals the same number of clusters;
- Even with data without private information such as building type or addresses clustering can be performed;
- Four clusters were identified in a two-dimensional space;
- Under normal conditions, LOW operating hours with HIGH demand is the least preferrable option (the specific technical details and the inclusion of the Kaposvár sugar factory may positively contribute to turn this finding into an advantage);
- Longer and stable operating hours are the most favourable – with low demand. Low demand with shorter operating hours is also welcome.

Any further steps, such as identifying meters and underlying consumers for cluster #1 from sampled data or possibly performing the test for another year should be part of a follow-up research. These should be considered as shortcomings or gaps as the primary goal was to evaluate and assess the potential for clustering and to identify clusters. Follow-up research could also carry out structuring / data analysis including private data (house size, type of use (private, office)).

The result showed significant heat demand at low operating hours – given the initial time of measurements, this is early in the heating period. The use of waste heat, such as the heat and methane gas produced by the sugar factory could be increased by additional sources. That would be a measure that could be taken without further research into the details of each cluster.

Inter-company waste heat utilization, which means that waste heat that cannot be used within the company can be used by third parties, for example, in commercial or residential buildings. The main challenges of this option are access to reliable data to compare and match waste heat potentials and demands, and the fact that these do not always match. At present, the most economically viable and feasible utilization of waste heat requires spatial proximity between the waste heat source and waste heat demand. Heat recovery or heat displacement are the most efficient and simplest technological approaches to use waste heat to increase overall energy efficiency and cost-effectiveness. Heat exchangers are often used for this purpose. Heat exchangers transfer waste heat to a transport medium, which then transfers the heat to other units. However, losses are incurred in such cases. The transfer of waste heat to third parties requires additional transport infrastructure such as local and district heating pipes, buffer storage etc. The advantage of local and district heating networks is that they have the flexibility to use a large number of different heat sources, which can be both centralized and decentralized. In addition, the heat network draws on different energy sources at different levels and points, whether it is summer or winter. The waste heat generated can thus be economically recovered, extracted and profitably fed into the heating network. As a result,

the company saves on cooling water costs, generates income from the sale of heat energy, and makes significant contribution to reducing CO_2 emissions, as the heat fed in would otherwise have to be produced elsewhere.

Glass is one of the most sustainable packaging materials available, made from natural elements, largely reusable and 100% recyclable. However, its production is energy-intensive, with furnaces operating at temperatures of over 1500 °C, 24 hours a day and 7 days a week, making glass production a significant and major source of waste heat. The auxiliary heat exchanger is typically located upstream of the plant flue gas treatment, so there is no need to lower the temperature - to the temperature supported by the filter - dilute the flue gas with external air or spray it with water (quenching/melting tower). The temperature and the amount of heat that can be recovered for a single production line are often not particularly high. This usually limits the use of recovered heat for power generation with steam turbines, at least not using other fuels to ensure the steam does not overheat. Organic Rankine Cycle (ORC) is an attractive solution to generate electricity from waste heat, even for low power and discontinuous flows of hot gases with temperatures around 300 °C or even lower. The ORC has a lower sensitivity to temperature and flow rate changes of hot gases, which allows for easier handling and eliminates the need for specialist staff. It has lower operating costs, does not require water treatment or consume water. The waste heat is initially used to produce high-pressure steam or supplied to consumers that require high temperatures. This, in turn, produces waste heat but at lower temperatures. Such waste heat is available as additional waste heat potential, which can be used, for example, for heating products, as feed water, or as boiler water. This leaves low-temperature waste heat below 100 °C, which often has no internal consumers. Instead of disposing of this energy, the best solution is to transfer it to a district or local heating network, which usually operates at fixed temperatures between 70 and 100 degrees Celsius. This is relevant as Şişecam (Şişecam is one of the most influential industrial enterprises in Turkey with a corporate history of more than 85 years. Şişecam was founded to meet Turkey's basic demand for glass products. Today, as one of the country's most powerful industrial conglomerates, Şişecam has become a global player in all key areas of the glass industry, as well as in the soda and chromium compounds businesses.), investing more than €200 million in the construction of a glass packaging plant in Kaposvár, south-west Hungary. The plant, which will be Şişecam's first glass packaging factory in Europe, will have the capacity of producing 330,000 tonnes of glass packaging material a year (*Glass online*, 2022).

The 4 identified heat demand clusters can be used to identify and integrate additional waste heat sources into sustainable heat production for the district heating in Kaposvár. One possible additional source has been mentioned above. But here again, further research and exploration would be needed, and technical feasibility should be investigated.

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