Design thinking and its application to problem solving

ABSTRACT: In this article, the authors implement the design thinking paradigm as a method to find solutions for specific problems and challenges within higher education. This approach was triggered by the continuous changes in technology and the requirements of the outcome-based curriculum in regard to graduate attributes. The authors also address the question as to whether researchers should be problem focused or solution focused in the process. Problem-oriented thinking is closely linked to critical thinking, and questions like *what*? and *why*?, whereas solution-focused thinking is linked to creativity and the question *how*. In this context, design thinking should be thought as a form of solution-based thinking, which is implemented to produce creative future results and/or creative resolutions to wicked problems. This article identifies how design thinking was implemented to provide innovations in outcome-based teaching and learning considering aspects, such us curricula, pedagogy, assessment methods and teaching spaces. The main goal was to improve graduate attributes and, as a consequence, the academy to industry transition. Using case studies to accommodate the new generation of learners, the authors argue in the article that user-oriented and outcome-based oriented design thinking is the suitable paradigm to ensure that these initiatives are successful.

Keywords: Engineering design, design thinking paradigm, wicked problems, outcome-based curriculum, experimental thinking, solution-focused problem solving

INTRODUCTION

This article identifies opportunities for design thinking, and how the design thinking paradigm was implemented to find solutions for problems associated with curriculum, pedagogy, assessment, learning space and the new generation of learners. Design thinking was used as a human-centered, open-ended problem-based approach to transform the way teaching and learning is conducted in engineering education, and to solve the different challenges that instructors and students are facing in the context of digital learning and of outcome-based curriculum [1][2]. As indicated by Pusca and Northwood [3], and as Grant Wiggins and Jay McTighe mentioned in their book *Understanding by Design*:

> *Teachers are designers. An essential part of our profession is the design of curriculum and learning experiences to meet specified purposes* [4].

As a starting point, the authors address the question as to whether researchers should be problem focused or solution focused in the process. An analysis is made based on the schematic representation in Figure 1. *Why* is the *guiding vision* of Riddell [3][5]. The questions *why* and *what* identify opportunities for design thinking and contribute to the formulation of the (design) problem to be addressed. Several examples that can be considered as open-ended problems related to academic education are indicated in Figure 1. The question *how* identifies design thinking as the enabler of forward-thinking ideas to find a creative solution to the problem. As a result of such analysis, it was concluded that problem-oriented thinking is closely linked to critical thinking, and questions like *why*? and *what?* help with the formulation of the problem, whereas solution-focused thinking is linked to creativity and as a result to the question *how*. Todd Henry in his book *The Accidental Creative* considers the *how* to be the creative strategy [6]. Since design thinking is a creative strategy to produce creative future results and/or creative resolutions to problems, it should be thought as a solution-focused thinking strategy.

In a learning-centred campus, student learning is the most significant goal of the university [2][7]. Thus, students should always be kept first in mind when addressing the *why* and *what* questions to formulate the problem, as well as the *how* when deciding on creative strategies to identify the best solution. Design thinking is considered as an *integrative* process [8], and is …*less about thinking and more about doing*, as mentioned by Baert [9]. In an integrative learning environment, empathy should be part of design thinking, since it is important to …*understand the experience, situation, emotion of the person you are working for* - the students [9].

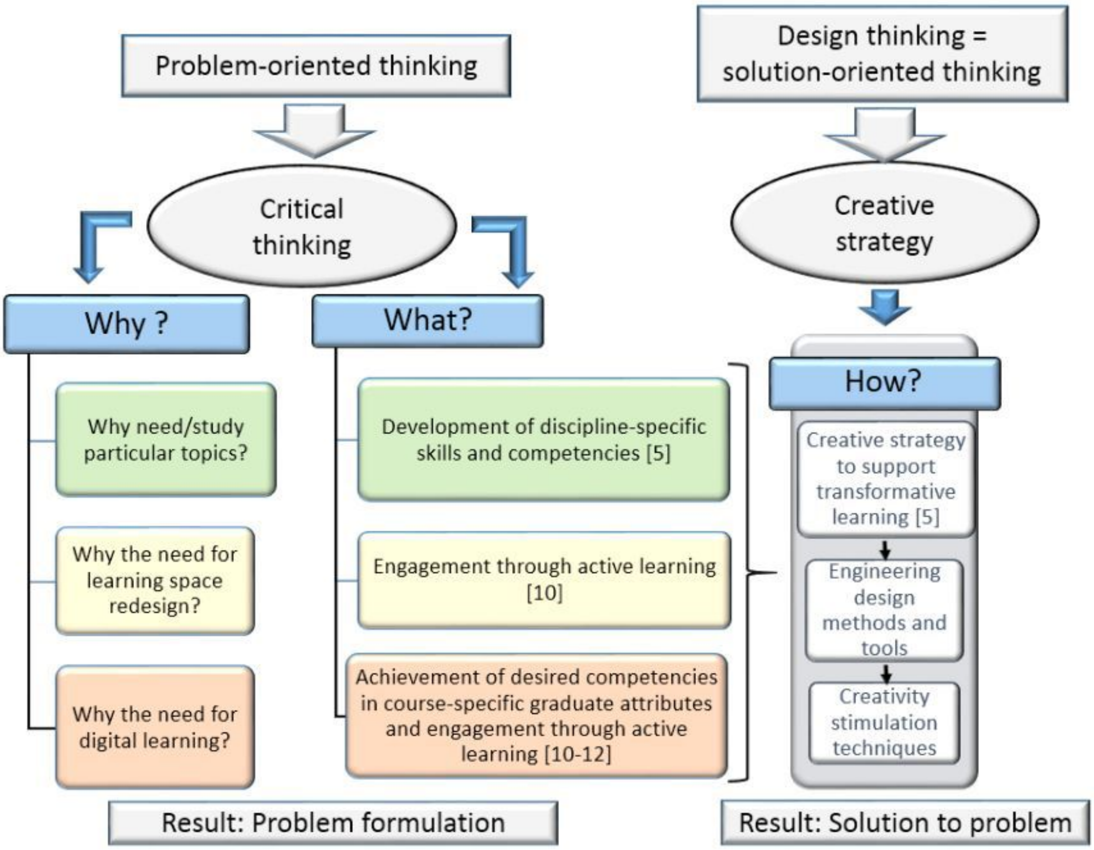


Figure 1: Is design thinking problem focused or solution focused?

DESIGN THINKING PARADIGM AND WICKED PROBLEMS

The term *design thinking* is often used as a unique approach to solving problems in innovative ways. Researchers in various disciplines are using the principles of design to solve problems. Tim Brown in his book *Change by Design: how Design Thinking Transforms Organizations and Inspires Innovation* has explored *design thinking* [10]. *Design thinking*, based on the same principles used by designers to produce innovative solutions for engineering problems, is considered by Brown to be the paradigm for solving complex problems regardless of the field of activity. According to Brown:

> *Design thinking has its origins in the training and the professional practice of designers, but these are principles that can be practiced by everyone and extended to every field of activity* [10].

Kimbell also explains that design thinking *has been appropriated in a variety of professions (e.g. business and sciences) to solve disciplinary problems in seemingly new ways* [11]. In the same context, Piotrowski explains:

> *Businesses are seeing that the process of design can bring innovative thinking to problem solving within the corporate environment. This methodology is called design thinking* [12].

Cairnes [13] and Northwood [14] pointed out that we are living in a *world of rapid discontinuous change and wicked problems*. As mentioned by Buchanan [8] the wicked problems approach was formulated by Rittel in the 1960’s. Also, in the first published report of Rittel’s idea, wicked problems are defined as:

> *A class of social system problems which are ill-formulated, where the information is confusing, where there are many clients and decision makers with conflicting values, and where the ramifications in the whole system are thoroughly confusing* [15].

As described by Rittel, design thinking and decision making is not a simple linear process when applied to solving wicked problems. The proponents of the linear process in design thinking consider the design process as *divided into two distinct phases*: structuring the problem identification and formulation, and structuring the search for solutions [8]. The first phase is considered an analytic sequence in which the designer determines all of the elements of the problem and specifies all of the requirements and the constraints. Problem identification and formulation is a very important phase, since a wrongly formulated problem will not lead to a successful design solution. The second phase, structuring the search for a solution, consists of synthesis and analysis sequences in which several possible concepts are evaluated to find the best solution for the problem. A comparison between the linear model for the design process and the wicked problem approach by Rittel, is presented in Figure 2. Buchanan argues that *the wicked-problem approach has remained only a description of the social reality of designing rather than the beginnings of a well-grounded theory of design* [8].

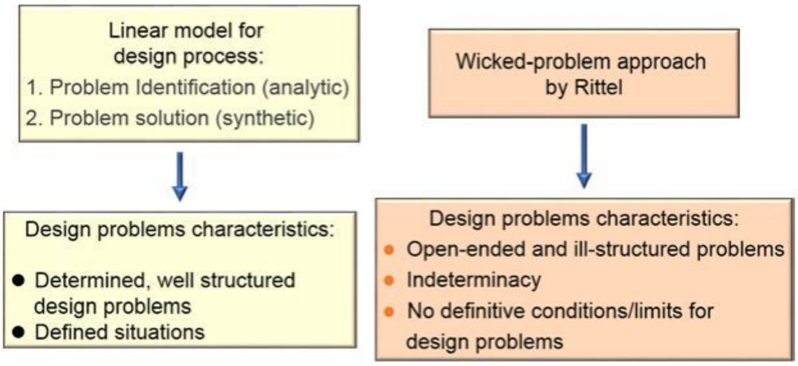


Figure 2: Design thinking as a linear process and the wicked-problem approach.

In an opinion piece on design thinking, Johnson indicates that its proponents consider that it is particularly well-suited for solving *wicked problems* [16]. He also argue that:

> *Design thinking is changing the way some academics approach teaching and research, the way architects design classrooms and how leaders seek to solve the world's most persistent problems* [16].

DESIGN THINKING IN ENGINEERING - A TOOL FOR PROBLEM SOLVING

Design educators use the term to explain how design thinking paradigm can be implemented to improve lives, solve problems and enable collaborations with non-designers [17]. Design methodology - as a tool for creative problem solving in engineering, has developed over time. Pahl and Beitz [18], Pugh [19], Voland [20] and Ullman [21] are few of the known authors of books on engineering design methods and methodology. Design thinking as a process, is a similar approach and descriptor to what engineering designers do. As Kelley mentioned [8][22]:

> *We moved from thinking of ourselves as designers to thinking of ourselves as design thinkers.*

Figure 3 is a schematic representation for the engineering design process, as the design thinking paradigm in engineering - an *effective problem-solving algorithm* [20][21]. This is a model-based definition for design thinking, as a sequential process.

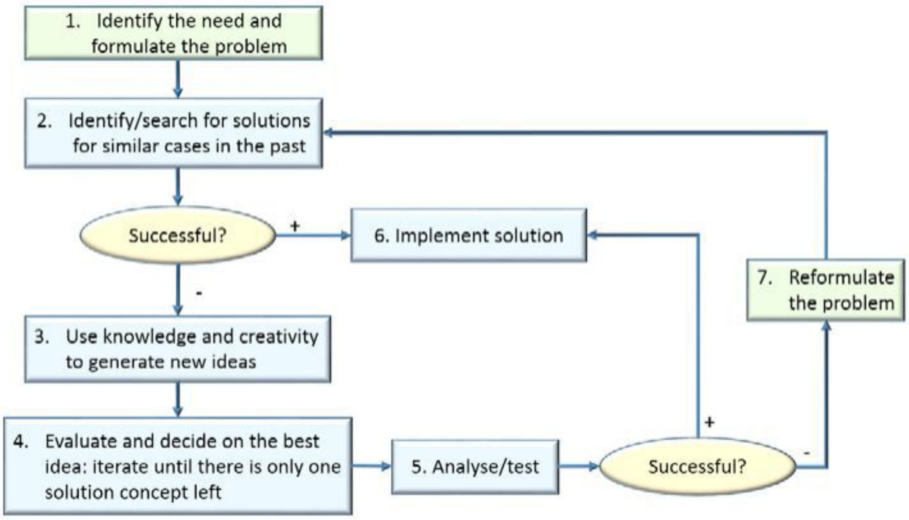


Figure 3: Schematic of the design thinking paradigm as an engineering design process.

The process starts with the need for identification and formulation of the problem, including any associated constraints. This first step is very important, since a well formulated problem is necessary in order to find the desired solution. As mentioned by Hall [23], and according to Horst Rittel's essay *The Reasoning of Designers* [24], there are often complex problems that require *disorderly reasoning*:

> *A design problem keeps changing while it is treated, because the understanding of what ought to be accomplished, and how it might be accomplished is continually shifting. Learning what the problem is IS the problem* [24].

First, the designer tries to associate the problem with similar cases from the past. If this approach will not provide any solution, the next step is to generate new ideas using knowledge and creativity as a form of experimental thinking.

Evaluation of these ideas using a decision matrix will lead to one solution that will be further analysed and tested. If successful, it will be implemented. If not successful, the problem needs to be reformulated, and the process repeats. This is an iterative process, i.e. a loop method. The main iterative loop with two iterations is shown in Figure 4.

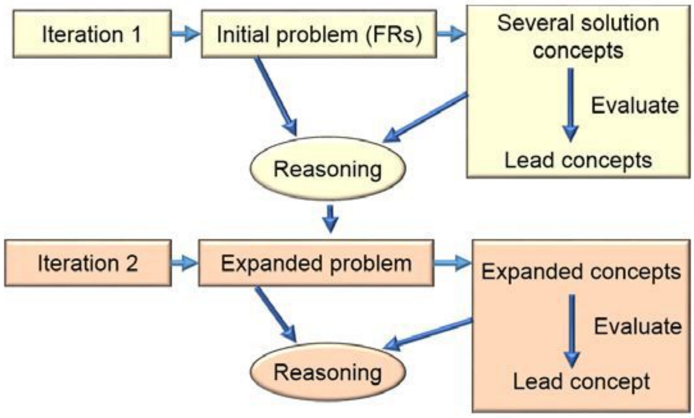


Figure 4: The main iterative loop with two iterations for the evaluation stage in design thinking [25].

This model-based definition gives a very clear and easy to understand description of what design thinking is. In fact, the concept is very complex and somewhat different from the design thinking process associated with other non-engineering activities. The difference consists in the tools and methods employed during the five main stages, stages 2 to 6 in Figure 3. The main common aspect is the use of creativity and creativity stimulation techniques, like brainstorming, analogy, inversion or checklisting using trigger questions.

Cross argues that there are *forms of knowledge special to the competencies and abilities of a designer* [26]. This has been demonstrated by the present authors in several applications involving the adaptive use of engineering design methods to solve non-engineering issues, such as course design for outcome-based curriculum [25], learning space [7], and assessment methods design [27][28].

DESIGN THINKING FOR CURRICULUM DEVELOPMENT

The suitability of the design thinking paradigm as an adaptive use of engineering design methods and tools to solve complex problems was demonstrated by the authors through empirical research conducted in the context of curriculum development [25][27][28]. The adaptive use of engineering tools has proven its effectiveness through the achievement of desired outcomes for problems associated with curriculum development regarding new and improved course design for an outcome-based curriculum. They also provide a qualitative evaluation and future opportunities for improvement, as described in Figure 5.

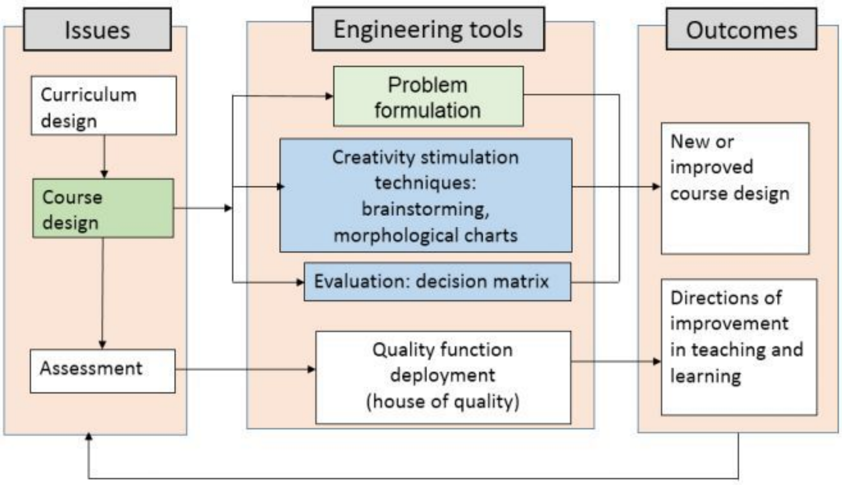


Figure 5: Design thinking for outcome-based course design.

Woods claims that findings in the literature, as well as his experience with methods for solving complex problems at McMaster University, have proven the effectiveness of the use of basic problem-solving strategies [29][30]. Douglas et al also discuss the problem solving strategies or heuristics used by engineers and support Woods' strategy based on empirical research [31]. It is what Woods [29] calls a *basic strategy* for solving complex problems - typically start with an *awareness of problem* stage, then a *definition stage* and close with an *evaluation* or *verification* stage. This strategy is composed of six discrete steps, which can be used in an iterative manner, similar with the design thinking paradigm proposed in Figure 3 and used by the authors to solve open-ended problems associated with curriculum design.

Some authors do not believe that problem-solving strategies as the design thinking paradigm described in this article are useful, because of the linearity (or step-by-step progression) [31] and the indeterminacy associated with the wicked problems [8][15].

This article indicates that the engineering design method can be considered as a design thinking paradigm both to solve any complex problems, because it provides a logical understanding of the design process, and a guide to achieve a solution to the problem. In medicine, there is also research to show the adaptive use of design heuristics as a useful strategy for problem solving and decision making [32], and the authors consider *the engineering study of* intuitive design*, that is, the design of transparent aids for making better decisions*. Visser also explores to what extent design thinking involves similar or different processes when implemented with different activities or disciplines [33]. Johnson explains why principles of design should be used in various disciplines to solve complex problems:

> *…with its emphasis on teamwork and its problem-based approach, design thinking is particularly well-suited to solving* wicked problems - *those big, ill-defined, complex, multifaceted issues that don't have a clear solution* [16].

Innovations in Local Public Transport–Significance for the Local Community

INNOVATIONS IN LOCAL PUBLIC TRANSPORT - A THEORETICAL APPROACH

Eurostat statistics indicate the persistent level of car use in the EU in the last 10 years. In 2014, passenger car transport accounted for 83.4% of land transport (measured by the number of passenger kilometres), in the years 2004–2014 the use of cars was in the range of 83–83.7%. There are visible changes in the use of other means of transport, in the case of trains it is an increase from 6.7% in 2004 to 7.6% in 2014, while the use of bus and trolleybus transport in the same period decreased slighty from 9.9% to 9.1% (Eurostat, 2017). In the context of urban traffic congestion, transport congestion, and environmental pollution, it is extremely important to promote mass transport among residents in order to improve mobility and reduce environmental pollution. Many cities plan and take initiatives to limit individual car transport in favour of public transport, cycling, and pedestrian traffic.

Public transport, cycling, and pedestrian traffic will become an alternative to owning and using one's own car only if those modes of transport are well organised, integrated, and accessible to passengers (Salonen, 2018; Buehler and Pucher, 2011). Data from the Quality of Life Survey, Eurobarometer on public transport indicates that it is popular especially in large European cities. Almost 20% of the residents use public transport in almost all cities studied, which results, on the one hand, from the quality and accessibility of those services and their territorial integration (e.g. within metropolitan areas), and, on the other, from urban congestion. Public transport has been modernised in many cities, and the process covered both the rolling stock and the transport infrastructure (UN-Habitat, 2016). The process was supported by EU funds. In 2007–2013, public transport entities from the European Regional Development Fund and the Cohesion Fund in the EU28 spent 0.8 Euros per EU citizen per year (Tab. 1) (UN-Habitat, 2016). Metropolitan regions were the main recipients of the interventions fulfilled in order to improve mobility, and reduce environmental pollution.

Annual per capita spending	Road transport	Railway transport	Water transport	Public transport	Multimodal transport	Air transport	Bicycle transport	Smart
Capitals of metropolitan regions	8.9	6.6	0.5	1.3	2.2	0.3	0.1	0.1
Outside of capitals in metropolitan regions	10.3	6.0	1.3	0.9	0.4	0.8	0.1	0.2
Outside metropolitan regions	21.4	8.2	1.2	0.4	0.5	0.4	0.3	0.1
Total	14.7	7.0	1.1	0.8	0.7	0.6	0.2	0.2

Source: UN-Habitat, 2016, p. 127.

Most public transport research focuses on economic issues, and the impact of public transport services and their privatization on the costs (Alexandersson *et al*., 1998), efficiency (Boitani *et al*., 2013; Pina and Torres, 2001; Egmond *et al*., 2003), and the quality and availability of services (Fiorio *et al*., 2013). The issue of innovativeness of public transport is also important (Ongkittikul and Geerlings, 2006). In order for the role of public transport to increase further it is necessary to implement innovative solutions that respond to environmental challenges and problems, to integrate transport modes, and to increase mobility. Innovation in public transport can be of different character and concern for specific facets of the service. Public transport has a technical dimension that applies to the means of transport, technological solutions used in the field of drivetrains, traffic control systems, and transport infrastructure. The process of delivery of the service is another dimension; it applies to the recipient expectations, ensuring the coordination and continuity of the process. The managerial competences of the operators providing public transport services, regulatory system, and adopted priorities in transport policy are yet another element of the service. Considering the above-mentioned components of public transport, innovation can be defined as a change affecting one or several of the mentioned feature vectors. On that basis Ongkittikul and Geerlings (2006) distinguished the following types of innovations in public transport: endogenous service innovations that apply to the development of competences and technical innovations, and exogenous service innovations generated by external factors, including intervention by public authorities.

The process of generating and transferring innovations in public transport is of interest to the EU, which undertakes a number of initiatives in this area. References to this issue could be found in the Urban Transport Package 2013 of the

European Commission (Urban Mobility Package 2013), which proposed measures for urban mobility supporting sustainable urban transport. One of the areas of the package was research and development within the framework of the CIVITAS 2020 initiative, under which cities, institutions, scientific units, and others will be able to develop and test new solutions in the field of urban mobility. The Clean Power for Transport package and the Intelligent Energy Europe (STEER) program are aimed at increasing the use of alternative fuels, also in public transport. The European Commission is also working with Member States on implementing intelligent transportation systems (ITS - travel information, traffic management, smart tickets, and urban logistics), which are essential for increasing safety and addressing issues related to emissions and congestion. Innovative solutions are also supported by the EU's through the promotion of sustainable urban transport plans, of cooperation in this area, and an observatory for sustainable urban transport. Innovative public transport solutions have also earmarked funding under Horizon 2020 to transform the European transport system into a more efficient one that would provide jobs and more efficient utilisation of resources. In the period 20014–2020, 6.3 billion Euros were allocated for that purpose.

An important factor generating innovative solutions in public transport is the pursuit of sustainable development (Tab. 2). In that context, the concept of sustainable transport is important, which means the establishing of the transport system, including the types of transport used, which do not threaten human health and natural ecosystems (Sokołowicz and Przygodzki, 2016). That results in the introduction of environmentally and user-friendly eco-innovations. Eco-innovations are new or improved socio-technical solutions that protect resources, mitigate environmental degradation, and/ or recover value from substances which had already been used in the economy (Jesus and Mendonça, 2017). In public transport, those will be related to low-emission mobility solutions.

The pursuit of public transport in line with the concept of sustainable development was started by numerous program documents developed within the framework of EU and global policies. The 7th EU environmental action program postulates, e.g. the development of an innovative approach to urban public transport and mobility. The need to develop efficient public transport and to promote ecological transport have been included in the Charter of European Cities and Towns Towards Sustainability. In turn, the UN General Assembly in September 2015 adopted the "2030 Agenda for Sustainable Development" which defined the goals of sustainable development. Sustainable transport is included in 7 out of 17 goals.

Many authors indicated that eco-innovations generate not only ecological but also social effects (Boons *et al.*, 2013, Carrillo-Hermosilla *et al.*, 2009; Kunapatarawong and Martínez-Ros, 2016; Rennings, 2000). Lin and Zheng (2016) emphasized the importance of eco-innovations for improving the quality of the environment but also for economic development. Eco-innovations are not only technological solutions that are beneficial for the environment (such as ecological powertrains that reduce emissions), but also can be a factor in the transformation of the value chain (Andersen, 2008; Kemp, 2010), initiating the recirculation and recycling of resources (Clark *et al*., 2016). Eco-innovations in that sense become a generator of circular economy processes. Kunapatarawong and Martínez-Ros (2016) proved that such innovations can have an impact even on employment. In connection with the above, it should be recognised that innovations in public transport in the field of low-emission mobility are part of the broader issue of circular economy.

Table 2. Types of innovations in public transport in the context of the latest development concepts

The concept of development	The nature of innovation	An example of innovation in public transport
Sustainable development	Eco-innovations – innovative solutions favouring the maintenance of balance in the ecological and socio-economic system, ensuring sustainable development, reducing environmental burdens.	Buses with electric, hybrid drive, reducing greenhouse gas emissions
Circular economy	Innovations initiating recirculation and recycling of resources	Organic bio-powered buses that allow the reuse of waste
Smart city	Technological urban innovations – innovative technical solutions using modern information and communication infrastructure and data management	Autonomous vehicles – automated driverless vehicles Passenger counting systems used for transport planning, occupancy systems and displaying information on the distribution of passengers in wagons / buses used to control the flows of passengers at bus stops and stations Communication systems between V2V vehicles, vehicles and V2C cloud, vehicles and V2I infrastructure. Systems for monitoring passenger preferences in the field of mobility
Crowdsourcing	Service innovations in which the client plays a special role as a prosumer, a consumer and co-creator of a solution	Personalised travel router

Sources: own work.

Another concept that is a source of innovation in public transport is the idea of a smart city, also referring to the assumptions of sustainable development. It is understood as a space creating conditions for a high quality of life in which services are provided on many levels of community and economic life on the basis of existing infrastructure and IT solutions (Chourabi *et al.*, 2012). One of the seven qualities of a smart city is intelligent transport and communication. It assumes achieving sustainable development by optimising transport solutions, taking into account technological, social, economic, and environmental challenges (Zawieska and Pieriegud, 2018). Thanks to that, cities should become enormous networks of high-speed connections, enabling the merging and moving of various resources in time and in space (Nowakowska, 2015). Additionally, a smart environment includes solutions that optimise energy consumption, including through the use of renewable energy sources and energy-saving technologies, as well as activities reducing the emissions of pollutants into the environment. Due to the development of the smart city idea, a special type of innovation can be distinguished: technological urban innovations (Meijer and Thaenes, 2018).

The idea of crowdsourcing is connected with the concept of a smart city. It means the mobilisation of knowledge dispersed in a crowd (Zhao and Zhu, 2014), stimulating people's creativity through ICT technologies and combining the roles of city users with the role of co-creators (prosumers). The main assumption of crowdsourcing is to recognise a resident as the source of knowledge about a city, as a user of urban space. As a result of the cooperation between residents, municipal authorities, entrepreneurs, research centres, and of combining different perspectives and knowledge it is possible to co-create innovative ideas and solutions for the problems in a city (Papadopoulou, 2017). It is a tool with strong potential for creating innovations in smart cities. In public transport the idea of co-creation can be used to design transport services by their clients (individual prosumption).

Some innovations result from the need to improve the travel process, which consists of waiting, getting on and off a vehicle, moving on the platforms, and traveling. Management solutions for passenger flows are aimed at loosening bottlenecks and congestion (especially at peak hours – in the morning and the afternoon).

3. INNOVATIONS IN PUBLIC TRANSPORT - GOOD PRACTICES

3.1. Bio Bus, Poo Bus[1]

Big cities nowadays have problems with increasing air pollution and smog. Buses fuelled with renewable energy (biomethane) have become the answer to this situation, contributing to the reduction of harmful emissions. The pioneering pro-

[1] Internal documents of the organization under study.

ject of GENeco assumed the introduction of the Bio-Bus into public transport, which is fuelled by gas obtained through the treatment of sewage, food waste from households, and manure. In nature, such a raw resource can be found in marshes and peat bogs. The rolling stock was introduced in Bristol in 2015, when the city served as the "Green European Capital". The project was supported by the local community and environmental organizations, mainly due to the environmental benefits of such a solution. It also minimizes the health problems of the local community caused byair pollution. Such a bus can be driven in with a full tank for 300 km. The gas tank is installed on the roof of the vehicle. It was calculated that the necessary amount of fuel is produced from domestic waste annually by five residents.

Another undertaking of that organization was the work on the utilisation of the gas in households, which would be a practical example of circular economy.

Biomethane has the same composition and properties as fossil fuels and can be a substitute for natural gas in public transport. Raw fuel comes from various types of waste and manure.

The following points summarise the production rules for that ecological energy source:

– waste is processed and pressed into a series of anaerobic fermentation cells,

– leftovers are heated to 32–42°C temperature and then stored in fermentation chambers for 12–18 days,

– microorganisms decompose biodegradable matter due to a lack of oxygen,

– a small amount of propane is added to the resulting raw product, which enriches its composition and calorific value,

– the final product undergoes a number of quality checks before being released for local distribution.

The use of such a fuel undoubtedly benefits the environment. When compared with widely used diesel, one can see that:

– emissions of solid particles are reduced to 97% – a microscopic substance that passes easily from the lungs to the bloodstream. According to research, one in twenty people living in urbanised areas will die prematurely, which is directly related to dust pollution (Xia *et al.*, 2015),

– nitrogen oxides emissions have been reduced by 80–90%. Those gases contribute to the formation of acid thrills, urban smog, and they adversely affect the development of vegetation,

– "wheel-to-wheel" analysis, i.e. from the fuel production stage, through production, storage, transport, to its use in buses, indicates that CO_2 emissions in biogas-powered buses can be reduced by 68% to 82% compared to traditional diesel. The situation is presented in Tab. 3, where carbon dioxide emissions in various types of vehicles using selected types of fuels are listed.

Table 3. Annual wheel-to-wheel GHG emissions for selected types of road vehicles

Vehicle type	Annual well-to-well CO2 emissions (tonnes per year)			Percentage in WTW emissions	
	Petrol/Diesel	Natural Gas	Biomethane	Natural gas vs petrol/diesel	Biomethane vs petrol/diesel
Passenger car (petrol)	1.70	1.39	0.20	-18%	-88%
Passenger car (diesel)	1.31.	1.39	0.20	+6%	-85%
LCV	3.98	4.28	0.82	+8%	-79%
Small rigid truck	18.07	20.43	4.91	+13%	-73%
Large rigid truck 26 t	48.21	55.94	10.61	+16%	-78%
Articulated truck (>32t)	135.38	136.23	82.00	+1%	-39%
Bus	57.53	60.96	10.10	+6%	-82%
Coach	46.14	53.12	9.60	+15%	-79%

Source: The role of natural gas and biomethane in transport sector, https://www.transportenvironment.org/sites/te/files/publications/2016_02_TE_Natural_Gas_Biomethane_Study_FINAL.pdf (15.01.2018).

As presented in Tab. 3, carbon dioxide emissions in the wheel-to-wheel cycle lean towards bio-ecological fuels in each vehicle type .The discussed eco-innovations are of a technological nature. They can also be seen as an example of conceptual innovations because they result from the changes in the views on the decarbonisation of transport through electro mobility. The effects of implementing electro mobility in reducing air pollution depend on the structure of resources used to produce electricity. The development of biogas drivetrains seems to be a competitive alternative in this respect.

3.2. Driverless Buses[2]

Another innovative solution in public transport are automatic driverless buses. The reason for implementing such a solution in 2015 was primarily to improve the quality of the services provided to local communities in low-urbanised areas. It is also important to reduce the costs associated with the remuneration of the person

[2] Internal document of the Department of Transport.

driving the vehicle. Due to the reduction of fees, the frequency of buses can be higher, which is especially advantageous in rural areas, where timetables are often not satisfactory for the residents. That solution contributes to a better adjustment of the frequency of the routes to the actual needs of the local community. However, there are doubts and questions about such a solution. If a bus has an accident, what will happen, who will notify the service when there is no driver in the vehicle? It is also necessary to amend vehicle insurance regulations, which until now have not included the payment of compensations for automatically-controlled buses. It is not a small challenge to convince potential clients about the benefits of such an innovation. The main concern is the safety of the people traveling by the vehicle as well as other road users (drivers of agricultural machinery, cyclists or pedestrians traveling on local roads).

Innovations related to unmanned buses can be subjected to a SWOT analysis, presenting the strengths and weaknesses, as well as opportunities and threats of the described project, which is presented in Tab. 4.

Table 4. SWOT analysis of driverless busses

Strengths	reduction of transport costs, originality of the solution, more frequent courses, better adjustment to the needs of final recipients
Weaknesses	no organisations that could be compared, high costs associated with testing and implementing automation
Opportunities	modern navigational systems, good quality of public roads, automation, public's openness to innovative solutions
Threats	competition, public concerns about safety, lack of legal solutions regarding insurance, social exclusion in terms of virtualisation

Source: own work.

Also in this case, one can talk about technical innovations but also about process innovations which result from a change in the way the service is delivered. It is also an example of an evolutionary innovation, where the change in the way a service is provided relates to the current group of users.

3.3. Real-Time Traffic Updates[3]

Another proposal to improve public transport in urban areas is the solution for informing residents and road users about the current traffic conditions in the area. Such messages are presented on digital boards placed on the rear, exter-

[3] Internal document of the Department of Transport.

nal walls of buses. The solution is primarily aimed at reducing congestion in London, which has had a positive impact on increasing the efficiency of road users' commutes and reducing the pollution of the environment in a given area. The vehicles have been equipped with Equitech IT Solutions electronic boards, which use GPS technology to provide accurate traffic information. The data is collected and updated from a network that is controlled 24 hours a day by the traffic control centre. The idea behind the solution was taken from taxi companies. Their cars are fitted with similar boards (of course much smaller), on which advertisements are displayed.

It is a typical technological urban innovation, part of the smart city concept, open data management in particular.

3.4. Green Areas in the London Underground

Passengers waiting for the arrival of the underground very often gather in one part of a platform, despite the fact that is the platforms are quite long. Such an excessive crowd makes it difficult to embark and disembark the carriages, causing dangerous situations related to the possibility of mutual deduction, fall or crush. Green painted lines graphically indicate the places where one can stand and wait for the arrival of the underground, and where the wagon doors will open. Travellers receive information that they should not stop in the area of the green line because they are intended for people who disembark and leave the underground station. Additionally, graphic signs have been placed on the walls with the inscription saying not to wait on the green lines. The situation is presented in Fig. 2 and 3.

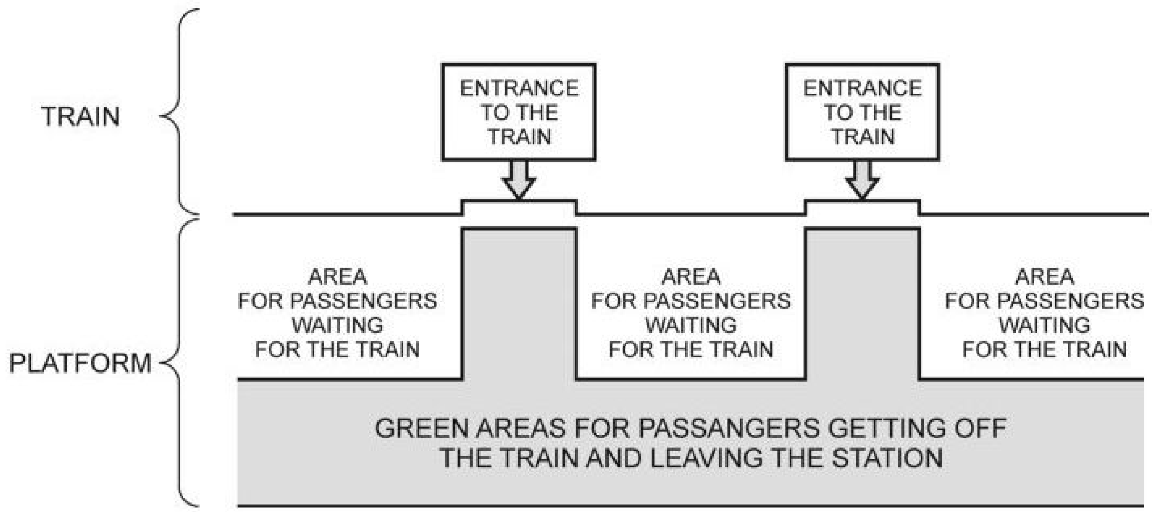


Fig. 2. Green areas in the London underground

Source: own work.

Fig. 3. Signs on the walls asking the passengers not to wait on the green lines
Source: own work.

In addition to graphic devices, information about the need to move along the track not causing unnecessary obstructions is aired on the PA. However, the latter solution has been in operation for a few years without any major effects. That is due to the fact that a significant part of the society better absorbs visual and graphic messages. The effectiveness of the introduced improvements and the preservation of recorders are controlled live, thanks to the installed cameras and monitoring. Transport For London hopes that the solution will be particularly helpful during the morning and afternoon rush hours. One should think about choosing the colour of the lines painted on. It is known that red and orange are identified with something that should be avoided, while green is rather associated with something that is inviting and friendly. Therefore, travellers may reflexively fall into the wrong places because green will be associated with security and the permission to stay in the place. Tests are being conducted at London's King's Cross and Victoria stations. Their results are to be known and made public in spring of 2018. When the experiment proves positive, the city authorities plan to extend such graphics to other mayor stations in the capital of Great Britain.

The presented innovation is of a conceptual and incremental nature. It involves introducing improvements without changing the way the service is provided to an existing group of recipients.

3.5. Crowding indicators

An innovation in informing passengers of the London underground about the current congestion of oncoming train cars is also currently being tested. The program assumes that the rolling stock being used should be modernised and equipped with data loggers that read the number of travellers. The solution is to lower the number of passengers in a car, and to better position those waiting so that they could intentionally enter the less crowded parts of the underground. The information is displayed on the electronic notice boards about the time of arrival of a train. The code used in this solution consists of colours (red, yellow, green) and notifications about the level of congestion in a train car. A graphic presentation of the current congestion of an underground train is depicted in Fig. 4. That is a typical incremental technological innovation.

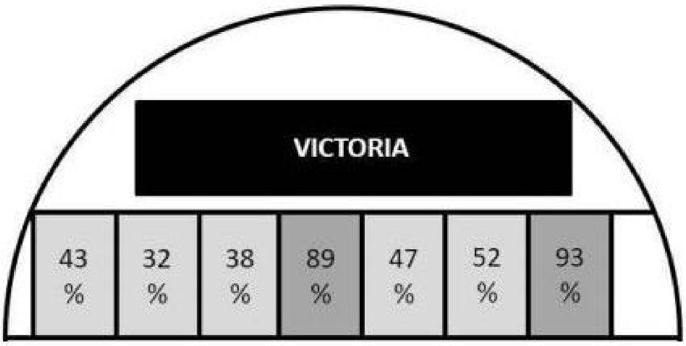


Fig. 4. Crowding information on screen

Source: own work.

The main benefits of using the solution are:

– increasing the throughput thanks to a smoother and faster embarking and disembarking the rolling stock,

– help in making better decisions for passengers choosing a less crowded underground car,

– greater travel comfort,

– minimising bottlenecks arising from embarking and disembarking the cars.

4. CONCLUSIONS

The quality of public transport services has a significant impact on consumer decisions regarding the choice of the way they travel. For that reason actions leading to its improvement are necessary. The means for achieving it are innovative solutions for various vectors of transport service features (Tab. 5). In addition to advanced technical innovations, changes not related to large expenditures and the use of advanced technologies are also possible.

Table 5. Directions of selected innovations in public transport in the local community contribute to meeting the needs, and respond to social expectations

Innovation	Environment	Health	Mobility	Security	Economic aspects	Social aspects
Bio bus, poo bus	Reducing greenhouse gas emissions	Reducing the frequency of respiratory and circulatory problems	They contribute to the increase of mobility, also over long distances	It affects ecological safety	Reduction of travel costs. Repeated use of resources in the economy, effective resource management	The community provides resources for the production of bio fuel Increased ecological awareness Active participation in local development
Driverless buses	–	–	They contribute to the increase of mobility thanks to the automation of the vehicle and its optimal use	They reduce the sense of safety of travellers as well as other road users No availability of insurance offers for this type of vehicles	Limiting the costs associated with driver compensation The system of individual ordering of a vehicle contributes to the reduction of costs related to the incomplete use of seats in buses	Positive reception of innovative projects by the local community. Better adjustment of travel frequencies for travellers
Real-time traffic updates	Impact on pollution reduction	Reduction of exhaust emissions	Important for road users. It gives them the opportunity to choose less crowded streets. It results in the reduction of travel time	They help reduce street congestion, and improve road safety.	Individual savings for drivers as well as for city administrations related to the elimination of the effects of air pollution	Improving the comfort of travel Access to up-to-date information An increase in the number of traffic sources related to congestion in a city Placing plates at the rear end of a vehicle contributes to better information reception

Innovation	Environment	Health	Mobility	Security	Economic aspects	Social aspects
Green areas in the London underground	–	–	Improving the flow of passengers at stops and stations	Increased safety, especially when embarking and disembarking a vehicle	Reduction of the costs related to passenger exchange	Time saving for passengers Effective lapping with information to passengers
Crowding indicators	–	–	Improving the flow of passengers at stops and stations	Increased safety, especially when embarking and disembarking a vehicle Smaller congestion of wagons reduces the risk of accidents during, e.g. sudden braking	The ability to predict the number of wagons needed to carry passengers at certain times of the day	Increased comfort of travel

Innovations can contribute to the reduction of negative phenomena in various areas, such as the environment, health, mobility, security, economic issues, and social aspects. The greater the complexity of the introduced changes, the more they contribute to meeting the needs, and respond to social expectations.

The examples of innovations in public transport presented in the article include service innovations of an endogenous character, mainly resulting from the application of new technical solutions. Usually, they are incremental so the solutions implemented do not change the way the service is provided. Their source is often a change in views that is a consequence of new knowledge.

The main conclusion from the analysis is that the introduction of innovations in public transport, in particular their compilation, significantly affects the local community. It mainly applies to the access to information which helps one save time, increase mobility, travel comfort, adjust the organisation of transport to the needs of the travellers, and increase travel safety or its personalisation. Fostering the ecological awareness of travellers is also important.

Innovations in public transport largely result from the pursuit of sustainable development, in particular a reduction of pollutant emissions and recycling of resources, as well as the factor of economic development. Therefore, they are a tool for achieving the objectives set out in the strategies for sustainable development and the decarbonisation of transport. In turn, the use of smart ICT in public transport is particularly important for the comfort of passengers.

INTRODUCTION OF PYTHON :

Python is a high-level, general-purpose programming language. Its design philosophy emphasizes code readability with its notable use of significant whitespace. Its language constructs and object-oriented approach aim to help programmers write clear, logical code for small and large-scale projects.

Python is dynamically typed and garbage-collected. It supports multiple programming paradigms, including structured (particularly, procedural and object-oriented), functional, and imperative programming. It is often described as a “batteries included” language due to its comprehensive standard library.

Python is one of the most popular programming languages in the world. It is used in a wide variety of domains, including web development, software engineering, data science, machine learning, and artificial intelligence. Python is also popular among educators and beginners due to its simple syntax and easy learning curve.

Here are some of the benefits of using

Python:

Easy to learn and use

- Portable and cross-platform

Powerful and flexible

Large and active community

• Wide range of libraries available

Open source

INTRODUCTION OF RASBERRY PI
:

The Raspberry Pi is a small, single- board computer that can be used for loT applications. It's a low-cost, programmable computer that includes GPIO (General Purpose Input Output) pins that can be used to connect and control external electronic devices.

The Raspberry Pi is used for:

• Real-time image and video processing

loT-based applications

Robotics applications

• Controlling lot robots

Learning to edit in languages such as Scratch and Python

The Raspberry Pi has the following

components:

• 1GB of RAM

• One HDMI port

• Four USB ports

• One Ethernet connection ● Micro SD slot for storage

• One combined 3.5mm audio/video port

● Bluetooth connection

The Raspberry Pi can run a variety of

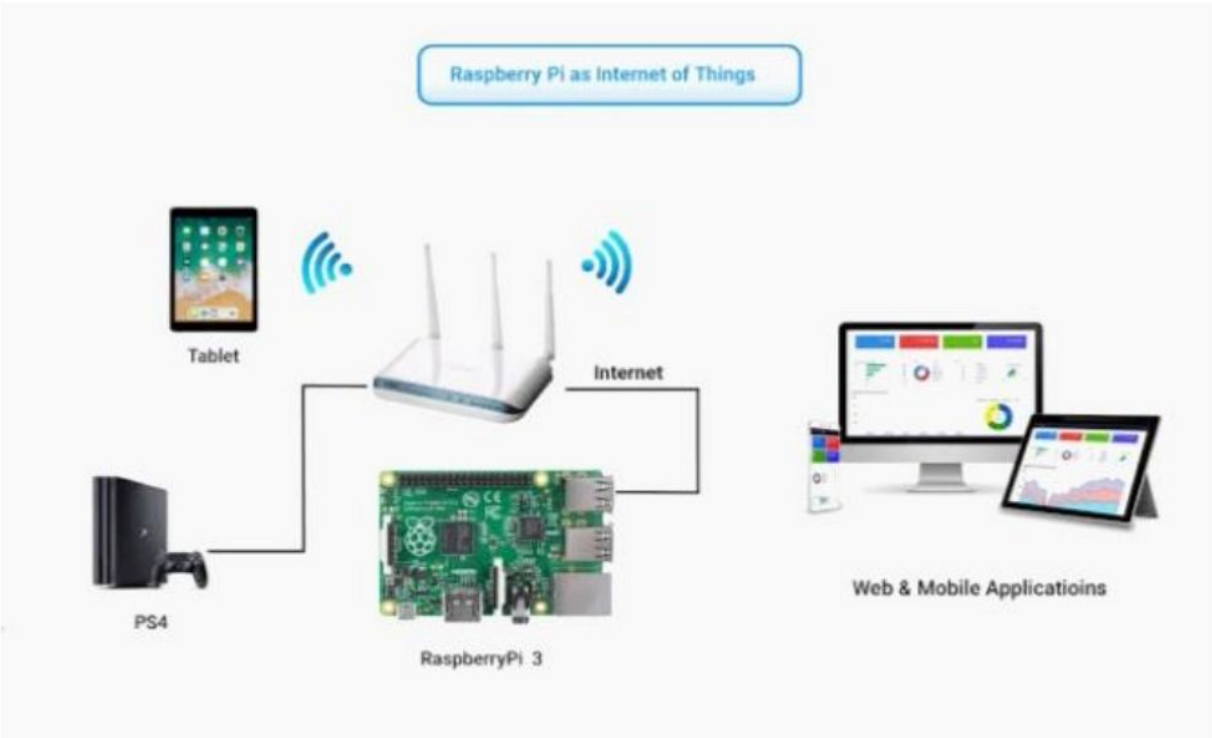
operating systems, including:

Raspbian (Debian Linux)

• Android

• Windows 10

• IoT Core



INTRODUCTION OF CLOUD :

Cloud IoT is a technology

Architecture that connects IoT

Devices to servers in cloud data

Centers. This enables:

• Real-time data analytics Better decision making

Optimization

• Risk mitigation

Management of connected devices at

Scale

• Access to computing services like

Storage and networking • On-demand information

• Fast and easy internal communication

Between devices

Cloud computing is based on the concept of allowing users to perform normal computing tasks using services delivered entirely over the internet. It’s accessible whenever and wherever there is an internet connection.

Some IoT cloud platforms include:

• Microsoft Azure IoT Hub

IBM Watson IoT

Google Cloud IoT

• Adafruit IO

Network operators such as AT&T, Vodafone, and Verizon may also offer their own IoT platforms.