THE 4th INTERNATIONAL CONFERENCE
MECHANICAL ENGINEERING IN XXI CENTURY

April 19-20, 2018
Faculty of Mechanical Engineering in Niš

Challenges in City Transport - Alternative Fuels and Door to Door Model

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Abstract— **The upcoming peak oil and the impact of exhaust emissions are threatening mobility and, as a consequence, the economy and the social live. City transport causes the biggest part of road transport emissions. Besides, by engaging mainly fossil fuels in the city transport, we are the most responsible for pollution of the places where more than 80% of the world population live in - urban areas. On the other hand, transport in city area of all types, (private and public, individual and mass) may contribute substantially in declining of the use of fossil fuels, by application of various means. Some of them may be very effective and not too expensive like for instance: 1) to switch on electricity and Hydrogen as a clean driving energy and 2) introduction of flexible transport (door to door, on demand, etc.) which enables to decrease the number of cars in urban centers to avoid congestions. This paper points out that city transport has a special role in the process of decreasing fossil fuel dependence, and the necessity for rapid alternative technology implementation, as well as development of the city transport system itself. Proposed is the introduction of door to door transportation model that offers a comfort comparable to personal cars (specifically for handicapped persons) and helps to lowering congestions on the roads.**

Keywords— **City transport, Alternative propulsion technologies, Transport system**

I. Introduction

The nature of mobility has changed over time, as travel modes have changed and individuals are traveling long distances. Motorized means are replacing the non-motorized, with a preference to individual means of transport such as the automobile. The use of motorized means (cars, motorcycles and buses) has pushed energy demand, especially for fossil fuels, to very high level. Today petroleum based or fossil fuels, are dominant in transport sector, where intensified energy consumption.

On the other hand people in villages, suburbs, highlands, as well as people work in isolated plants and restricted areas, far from the traffic lines are forced to use their cars, contributing to the congestion, fossil fuel wasting and pollution in urban areas.

Generally, the reasons why people use cars for city transport are numerous: uncomfortable public transport, habitation places not covered by public transport, inaccessibility (persons with children, elderly people, handicapped, etc.), inflexibility (moving out of routine), bad habit created by cheap fuel and used vehicles, and so on.

Because, the economic wealth is created in urbanised areas, where most citizens live, obviously that, the city transport is the prime mover of economy.

City traffic and traffic flow have the greatest impact on the exhaust emission and air pollution, specifically in the street canyons, zones of city centers etc. [1]. Moreover, in area of city traffic it can contribute substantially in declining of exhaust emission, by application of various methods. Some of them may be very effective and not too expensive like for instance:

- To switch on alternative fuels, natural gas and Hydrogen as clean driving energy, with parallel introduction of flexible transport which enables to decrease the number of vehicles in urban centers to avoid congestion [1], [2]–[7]; and
- Further optimization of vehicles and internal combustion (IC) engines by lowering internal friction and mechanical losses, in order to reduce fuel consumption and exhaust emissions [8], [9]–[15].

If the number of personal cars were decreased significantly in city transport, tremendous results would be achieved concerning fuel economy, environmental protection and social life. As a contribution to above mention serve the next facts: enormous fuel prices on the market and restrictions as well as penalties for exceeding of allowed exhaust gas emission. Therefore, alternative fuels and new bus propulsion systems have an increasing role in the public passenger transport system [2], [3]–[7].

The transportation system that will offer a high quality city transport service and comfort comparable to personal cars, and that will be close to the potential users, is needed [16]. Such the transportation system as an add-on to conventional transit service is in the focus of this paper. It consists of two integral parts:

1. An advanced city bus or minibus as an appropriate transport means (introduction of alternative fuels and technologies for city transport); and
2. The door to door transportation model which will bring the transport service close to the users, parallel with an appropriate information and communication system which will enable passenger information and effective management.

Such the transport system should offer a "shuttle for everybody" in everyday use and be an effective means to clean the majority of cars off the roads and the cities [16]. That would be one of the most effective, the least expensive and the fastest for implementation way for contribution to direct and indirect fuel economy and accompanying results.

This paper will outline each of the components of proposed transportation system with focus on its first component – an advanced city bus with alternative propulsion system.

II. Alternative Fuels and Technologies for City Transport

Although city transport is dominated by private car use, from the point of view of sustainable mobility and costs/effectiveness the city buses should play an important role. Mature and developing technology aiming towards increased fuel economy and decreased gas emissions, specifically carbon dioxide (CO_2) that will provoke increasing penalties, are the same for all road vehicles. There is a variety of alternative fuels and technologies for cars and buses that may be used for the benefit of fuel economy and gas emissions [2], [4].

In order of effectiveness and complexity (costs), the following possibility and alternatives may be implemented for both cars and city buses.

II.1. Good Maintenance, New Vehicles and High Quality Fuel

Many old cars and buses, specifically in developing countries, are not maintained properly, leading to high emissions and low fuel economy. Maintenance systems could be strengthened quite cheaply. Ultra-low-sulphur diesel, in combination with advanced emissions control technologies can substantially lower the harmful emissions from diesel vehicles [10], [11].

Classic new buses built for Organisation for Economic Co-operation and Development (OECD) countries are far cleaner than many buses built in developing countries. Such buses built in developing countries that will use them, may be a lower cost alternative and help develop the vehicle manufacturing industries in each country. Improvements should begin with better engines [2], [3]–[7]. New cars and high quality fuel complying with new emission standards reduces substantially emission and improve fuel economy [8]. As to the cars that participate in city (urban) transport in enormous quantities, moderate engine power (smaller cars) would be highly appreciated.

II.2. Alternative Fuels

The gaseous fuels as compressed or liquefied natural gas (CNG or LNG) offer the possibility for clean buses and cars [2], [6], [17], [18]. For optimal performance, engines designed to run on these fuels should be used rather than converted from diesel or gasoline engines [17], [19], [20]. CNG engine is a good alternative to diesel engine. CNG engines operate with a three-way catalytic converter and eliminate nitrogen oxides (NOx) problems while offering comparable efficiency.

As example, taking in mind the experience of leading manufacturers of buses, the mechanical engineers in domestics Production Company from Kragujevac city have successfully designed a prototype of fully low floor city bus with CNG drive, on the homologated chassis produced by MAZ factory, as shown in Fig. 1. [2], [3], [6], [17], [18].

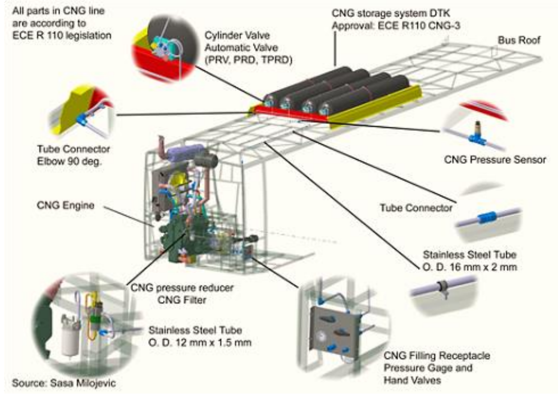

Fig. 1 Module with aluminum tanks for CNG, and position of their mounting on the city bus roof

Generally, the viability of different fuels in different cities depends in part on fuel availability and fuel supply infrastructure. Installation of refuelling infrastructure can take time and will be costly, and bus companies must be trained in the handling and use of gaseous fuels.

The problem is also the lack of current market demand for CNG vehicles. Unfortunately, the CNG filling station network in Europe is still incomplete, and although potential remains on the north-south axis, the situation is far worse from east to west. All of this compounds the difficulty of bringing monovalent products optimized for CNG to the market.

Biofuels are a good alternative concerning gas emissions, but without subsidies their costs may be high. On the other hand, production of some of them is at the expense of food production.

We are analyzed also the possibilities for production of biogas from landfill and agricultural crops. By upgrading biogas to bio-methane we produce the high quality fuel for mobility systems causing lower exhaust emission specifically particulate matter, sulfur compounds, non-methane hydrocarbons and nitrogen oxide, as well as smog and noise pollution in the atmosphere [21].

II.3. Hybrid Electric Drive

Hybrid-electric propulsion system is the most effective concerning fuel economy and along with it gas emission, specifically (CO_2) for both cars and city buses. This technology is complex, Fig. 2 and costly for investment in new buses and for operation. Thus it will be out of reach for many small transport service providers. But it is increasingly seen as part of the transition to fuel cells since it employs the same type of electric-drive system, and because this technology appears likely to be commercialised much sooner in city transport [22].

Hybrid electric vehicles (HEVs) are powered by an (IC) engine or other propulsion source that can run on conventional or alternative fuel in combination with an electric motor that uses energy stored in a battery. Because (HEVs) cannot plug in to off-board sources of electricity to charge the battery, one of solution is the vehicle uses regenerative braking and (IC) engine to charge.

(HEVs) can be designed as mild or full hybrids (in series or parallel configurations).

Fig. 2 City bus with integrated hybrid propulsion system

Mild hybrids (micro hybrids) use a battery and electric motor in combination with diesel engine and have integrated start-stop system usually, which shut off the (IC) engine when the vehicle stops (red traffic light or in stop-and-go traffic).

From the second side, there are full hybrids which have larger batteries and more powerful electric motors on the vehicle. Full hybrids can operate using electricity along, which is not the case with micro hybrids that helps diesel drive. These systems cost more compared to micro hybrids but provide better fuel economy benefits.

Regarding to the ways to combine the power from the electric motor and the (IC) engine to the drive wheels, on the market there are bus conceptions in form of parallel or serial hybrids.

Parallel hybrid propulsion system connects the (IC) engine and the electric motor to the wheels through mechanical coupling. Both the electric motor and the internal combustion engine drive the wheels directly, Fig. 3 [23].

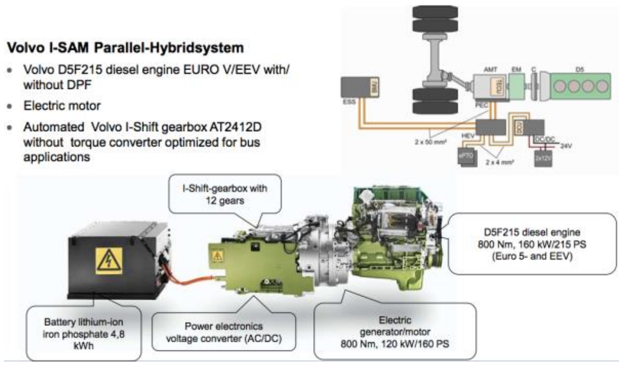

Fig. 3 Parallel hybrid propulsion system for city bus Volvo 7900 Hybrid

As example, Scania has chosen a series hybrid design for city buses, which has no mechanical connection between engine and wheels, and use only the electric motor to drive the wheels, Fig. 4 [24]. The energy obtained by recovering brake energy or supplied from the (IC) engine is stored in supercapacitors mounted in the roof. Supercapacitors are far more efficient than batteries in rapid charge and discharge cycles.

The series-hybrid powertrain permits the optimised operation of the (IC) engine regarding to fuel consumption, noise and exhaust emission. As example bus use stored energy when accelerating and this is important in urban conditions with a lot of stop-and-go driving due to the high degree of regenerative braking possible.

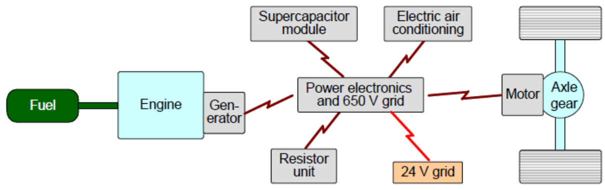

Fig. 4 Scania series hybrid powertrain for city bus of new generation

Series hybrid propulsion systems are used in plug-in and electric vehicles, too. Plug-in hybrid electric vehicles (PHEVs) have (IC) engine and an electric motor, which uses energy stored in batteries. All electric vehicles (EVs) or battery electric vehicles (BEVs) use a battery pack to store the electrical energy that powers the motor. (EVs) batteries are charged by plugging the vehicle in to an electric power source. Although in the world most electricity production contributes to air pollution, (EVs) are categorized as zero-emission vehicles because they produce no direct exhaust emissions.

With increased costs of operation of conventional buses and with the increased implementation of the hybrid electric technology, its costs may drop down quickly and as a result it may become cost/effective very soon.

II.4. Fuel cells (Hydrogen) propulsion system

There are two possibilities to produce electricity on the vehicle with fuel cells: Hydrogen stored or produced from other fuels by transformers. Fuel cell systems are also very complex, Fig. 5 [22], and its implementation will be a big step. But once experience is gained with (HEVs), and where possible with gaseous fuel vehicles and refuelling infrastructure, cities may be more prepared to deal with operating and maintaining fuel cell buses.

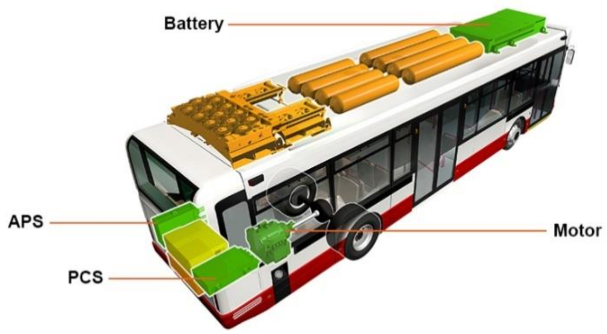

Fig. 5 Fuel cell technology implemented on the city bus

Using propulsion control system (PCS), electric power from battery and the hydrogen fuel cell engine is blended to provide power to the wheels and the electrified accessories. Regenerative braking also contributes to vehicle efficiency. The fuel cell engine uses hydrogen to generate all of the electricity needed for the bus.

If buses with on-board reforming are introduced, then the complexity level and importance of good maintenance practice will be even greater. Fleet operators, i.e. urban transport service providers, are the closest to use this technology since they may have their own refuelling infrastructure. However its implementation will need time for competence building process. It is costly but totally clean and may be independent from fossil fuels if the hydrogen is produced from water and electricity. Thus electricity and hydrogen transport and storage systems will play the most important role for implementation of the fuel cells technology. Cars will wait until an appropriate infrastructure is built.

As contribution, it is proposed a prototype of fully low floor city bus with hydrogen propulsion system. The prototype bus is equipped with the original gas (IC) engine. Engine is designed to work only on compressed gaseous hydrogen (CGH_2) [4], [7].

On the Fig. 6 are shown parts of the installation for (CGH_2) supply from bus roof mounted gas cylinders to the engine that is proposed to prototype version of (HyS) bus.

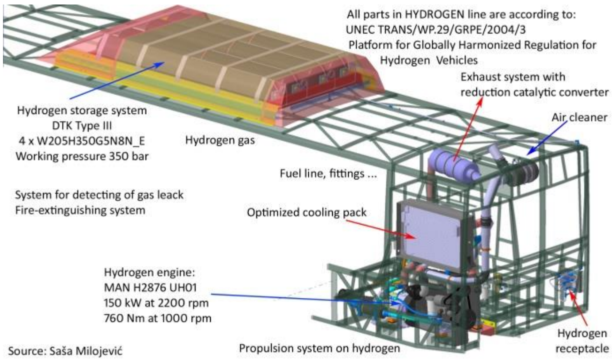

Fig. 6 Sketch of the (CGH_2) fuel line equipment installed on the bus

III. Door to Door Transportation Model Supported by an Advanced Information System

All alternatives from biofuels up to the hydrogen and electricity may be rapidly implemented in city transport. Congestion on the roads is one of the biggest causes for fuel wasting and pollution. It is mostly caused by personal cars used in city transport. Fuel economy is achievable in amazing quantity in city transport by various measures. One of them is relaxing congestions by offering car users high quality transport services with comfort comparable to cars.

As pointed out “door to door” model in public transport combined with Passenger Information System (PIS) is a transportation system that could tremendously decrease the number of cars in everyday traffic. Specifically, small passenger vehicles (buses or minibuses) that may bring closer the transportation service to the users, increase the frequency, increase the speed and offer comfort comparable to individual cars may change the behaviour of many car users.

Similar transportation model, accompanied with an information and communication system, is implemented in many cities in various modalities in order to serve particular needs [16].

Proposed transportation model, exists more or less as a particular service for passengers’ with specific needs, and has a little or no impact on nowadays urban transportation problems.

One may imagine a variety of transport service in order to bring the transport service as close to the potential users as possible. From the planned “door to door” service where passengers are pick-up at the door and brought to the destination of each of them, up to the customized service that feed the big traffic lines, Fig. 7, there is variety of different possibilities.

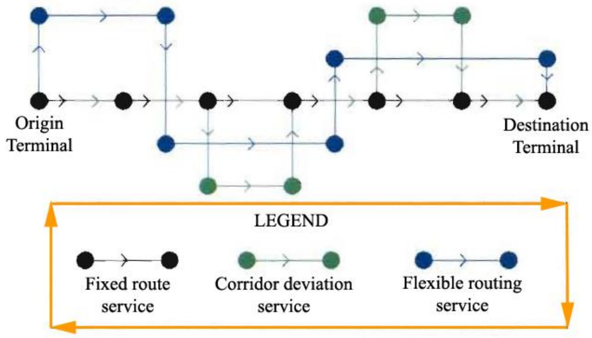

Fig. 7 Illustration of various service plans

In a basis fixed route, the bus or minibus with alternative propulsion system would operate in identical fashion to a conventional bus. It would follow a rigid schedule on a fixed route. In the corridor deviation service, the minibus can deviate to call at a few on-call locations, but must return to the fixed route path in order to call at all the normal fixed route stops. In the flexible routing mode, the normal route service end stops are not followed at all, and the bus or minibus is routed like a dial-a-bus to simply pick up and discharge passengers at the on-call locations based on calls for service from the passengers. Of course the bus would begin and end each trip at its end-point terminals.

Reliability is important, and to ensure this the buses must be controlled by an Advanced Vehicle Monitoring and Control System (AVMC System) that tracks the location of buses and provides two-way communication between the buses and the dispatcher so that any deviations can be dealt with expeditiously. In addition, there should be the (PIS), which would include displays at all major stops indicating when the next few buses were to be expected (based on actual location, not schedule), and similar information would be available to others through telephone and personal computer source. Additional information resources, such as recommended routes in response to inquiries, could also be included. (PIS) and its relationship to vehicle operations and management are shown in Fig. 8.

The combination of short headways and small vehicle size both make tailoring the service to do special needs of travellers on board a particular vehicle trip possible with far less disruption to the service than is possible with large vehicles. With modest and prudent slack in the schedule should enable either accommodating a single wheelchair-bound traveller without divesting the schedule, a serious problem with larger high floor buses where the delays for boarding and alighting extend to many minutes. And the same slack can be used to accommodate modest route deviations on demand. Passengers calling for such a deviation in order to board can be told via whatever communication medium is used that the next bus will not be able to stop, but that the following one, expected at the specified time, will do so. And given that the intended market is primarily short trips, and routes would typically be short, the effect on schedule adherence should not be excessive. At times when the number of passengers is not sufficient to justify a fixed schedule and route, various types of on demand operations plans can be used. At one extreme, this would be like a dial-a-bus service, the minibus moving as needed to carry the passengers. At other times various combinations of a fixed route and route deviations could be used.

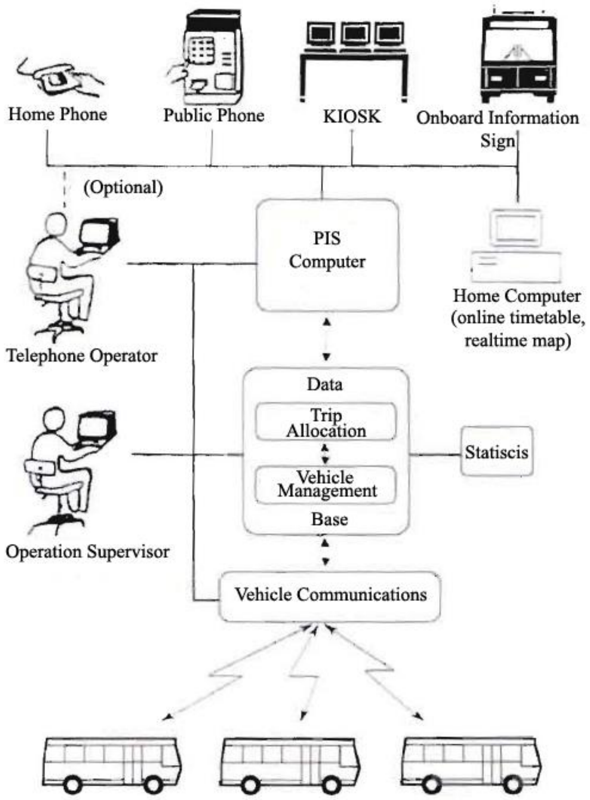

Fig. 8 (PIS) and its relationship to operations and dispatching

IV. Expected Benefits

Tremendous benefits may be achieved by decreasing the number of personal cars used for public transportation concerning fuel economy, gas emission, and business activities, by implementing the "door to door" transport system as an add-on to the conventional transit traffic service. The example below gives evidence of it. Calculation is made based on 100.000 vehicles on the roads in rush hours, which corresponds to a medium sized town. If, due to the implementation of the new transport service, in the first year the decrease of the number of cars were 5% and continues to decrease for additional 2% each year, the total decrease after the 3rd year would be more than 20%, and after 5 years the total decrease would be about 50%, Table 1.

TABLE 1 Decreasing the Number of Personal Cars

Year	1	2	3	4	5	6
Yearly decrease	5%	7%	9%	11%	13%	15%
No. of Cars (x1000)	95	88,35	80,39	71,55	62,25	52,91
Total decrease	5%	12%	20%	28%	38%	47%

As example, if there were only 1.000 low floor minibuses in a country offering high quality "door to door" transport, they would transport at least 200.000 passengers each day. Now, if 20% of them were former car users, 40.000 cars would stay in the garage and about 240.000 litters of fuel would be spared and not burned in cities. At yearly level it makes more than 2 million litters of fuel not burned in city centres and saved enormous quantity of exhaust emissions, specifically (CO_2).

V. Conclusions

The transport sector has seen fast growth in the number of vehicles and the consumption of transport-related energy. This has led to many problems including noise, pollution, congestion, accidents and deteriorating infrastructure.

Public transport is an important alternative to the car. It plays a major role in the bigger cities where it carries (2.5–3) times as many people as private transport. Public transport is also important for households who do not have a car.

Public transport may play an important role for the benefit of road transport in general by rapid implementation of all the possible alternatives step by step but very quickly, starting with the least expensive. Any promising alternative technology should be given a chance to develop and to demonstrate its costs/effectiveness.

Fixed uses sooner or later will have to leave gaseous fuels for the benefit of mobile use. Infrastructure for refueling gaseous fuels must start developing rapidly. But moderate (read acceptable) costs for road transport will not be established till there is electricity in abundance for fixed and mobile uses. And no country may stay aside and watch the world go by.

The add-on transport system which will complement the conventional transit in cities, proposed in this paper, consists of two integral components: 1) to switch on electricity and Hydrogen as a clean driving energy and 2) introduction of flexible transport (door to door, on demand, etc.) which enables to decrease the number of cars in urban centers to avoid congestions. Each of these components must be well thought and thoroughly integrated in the system in order to answer to very demanding upcoming overall conditions and needs of the community.

Besides, it offers opportunity for development of new business activities for industrial and various services inside of new small and medium sized enterprises (SMEs).

A pilot project implementing such a system in cities like Kragujevac, Kraljevo, Čačak, Novi Sad and Niš or Belgrade would represent a special experience, where mobility may be improved and the ambient may become much more pleasant, getting rid of personal cars on roads and streets. Specifically, also touristic organizations can use proposed transportation systems in order to better meet the needs of tourists.

Acknowledgment

This paper is a result of the researches within the project TR 35041 financed by the Ministry of Science and Techno-logical development of the Republic of Serbia.

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UNIVERSITY OF NIŠ
FACULTY OF MECHANICAL ENGINEERING IN NIŠ

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MECHANICAL ENGINEERING IN XXI CENTURY

PROCEEDINGS

Niš, April 19 - 20, 2018

Publisher:
Faculty of Mechanical Engineering in Niš
Prof. Dr Nenad T. Pavlović, Dean

Editor:
Prof. Dr Predrag Janković

Technical support, design & prepress:
Asst. Prof. Dr Aleksandar Miltenović

Number of copies:
200

Printing:
SVEN Niš

CIP- Каталогизација у публикацији
Народна библиотека Србије

621(082)
681.5(082)
007.52(082)

INTERNATIONAL Conference Mechanical Engineering in XXI Century (4 ; 2018 ; Niš)
Proceedings / The 4th International Conference Mechanical Engineering in XXI Century, Niš, April 19 - 20, 2018 ; [organizers] University of Niš [and] Faculty of Mechanical Engineering in Niš ; [editor Predrag Janković]. - Niš : Faculty of Mechanical Engineering, 2018 (Niš : Sven). - [16], 534 str. : ilustr. ; 30 cm

Tekst štampan dvostubačno. - Tiraž 200. - Str. [9-10]: Preface / Nenad T. Pavlović. - Bibliografija uz svaki rad. - Registar.

ISBN 978-86-6055-103-2

1. Mašinski fakultet (Niš) 2. Univerzitet (Niš)
a) Машинство - Зборници
b) Роботика - Зборници
c) Системи аутоматског управљања - Зборници

COBISS.SR-ID 261069580