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EIC Column

Editor in Chief's Note on the Green Hydrogen Fuel from Solar / Wind Power

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ABSTRACT

Renewable and sustainable energy has an evolving story as the ongoing trade war in the world is influencing crude oil prices. Moreover, the global warming is an inevitable consequence of the worldwide increasing rate of fossil fuel utilization which has persuaded the governments to invest on the clean and sustainable energy resources. In recent years, the cost of green energy has tumbled, making the price of renewables competitive to the fossil fuels. Although, the hydrogen fuel is still extremely expensive compared to the crude oil price, investigations about clean hydrogen fuel production and utilization has been developed significantly which demonstrate the importance of the hydrogen fuel in the future. This article aims to scrutinize the importance of green hydrogen fuel production from solar/wind energy.

1. Introduction

The global energy demand by the year 2050 is estimated to be in the range of 600–1000 EJ. Currently, about 80% of the worldwide energy demand is supplied by fossil fuel resources which the present rate of fuel consumption will conduct the reservoirs to be depleted within the next 50 years^[1]. Moreover, concerns about greenhouse gases (GHG) emissions from fossil fuel powered vehicles have highlighted the need of renewable energy with minimal negative environmental effects. The share of renewable energy by the year 2025 is predicted 36% of the total worldwide energy demand with hydrogen shares of 11%. The strong support of hydrogen production technologies will drop the use of coal and crude oil

to 36.7% and 40.5% respectively by 2030^[2]. Transportation sectors release about one-fifth of total global emitted Carbone dioxide (CO₂) due to fossil fuel consumption^[3]. Consequently, transition to the alternative fuel powered engines in the transportation system is vital in the world's future energy scenario. In this regard, hydrogen powered engines are considered promising technologies for vehicles energy supply^[4]. There are precious benefits to using hydrogen instead of fossil fuels in transportation engines. Hydrogen is an environmentally friendly fuel since it emits only H₂O when used in a fuel cell engine^[5]. Using hydrogen-fueled internal combustion engine (H2ICE) systems or fuel cell (FC) propelled vehicles is promising for the transportation sectors.

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2. Solar/Wind to Hydrogen

As the lightest and simplest element on the earth, hydrogen consists of only one electron and one proton which does not exist in nature and should be produced. Hydrogen is considered as the fuel of future which will reduce the dependence on crude oil and minimize the toxic emissions from transportation system. The energy of hydrogen is approximately 122 kJ/g, which is 2.75 times more than hydrocarbon fuels. Due to the environmental issues and energy policies, using hydrogen in transportation system has extensively been developed in both electric fuel cell (FC) vehicles and combustion engines. In the current modern fossil fueled power transportation systems, air pollutants such as carbon monoxide (CO), volatile organic compounds (VOCs) and nitrogen oxides (NO_x) are unavoidable which have significant negative impacts on the people health [6]. Considering life cycle assessment of hydrogen fuel, it is obvious that various hydrogen production technologies are associated with pollutant formation [7]. However, evaluating various indicators such as sustainability, environmental impacts and economic issues, hydrogen could be considered as a clean fuel [8]. Furthermore, the efficiency of hydrogen FC engines is three times more than fossil fuel powered vehicles which highlights the importance of research on hydrogen production and utilization [9]. There are several crucial impedes in widespread use of hydrogen fuel in transportation systems which require tenacious investigations. Hydrogen is not available in nature and its production process is currently expensive. The hydrogen energy density is 10 MJ/m³ which is miniscule in comparison to propane and methane by 86.7 and 32.6 MJ/m³ respectively, and consequently a larger fuel tank is required for hydrogen powered vehicles [10]. Moreover, hydrogen can be leaked from its vessel due to the small size of its molecules.

Currently, approximately 95% of the worldwide hydrogen is produced from fossil fuels such as oil, coal and natural gas following by 4% by electrolysis process and 1% from biomass utilization [11]. As a long-term goal, production of green hydrogen from renewables such as solar and wind energy (intermittent renewables), biomass, hydro, geothermal (non-intermittent renewables) and nuclear energy has been noticed by hydrogen researchers [12]. Although, mining and collection of renewables is exorbitant due to their decentralized characteristic, the recent exponential growth in green energy generation technologies have made the renewables commercially competitive to the non-renewable resources [13]. Renewables can produce hydrogen locally; however, they are not adequate sources to supply sufficient hydrogen to meet the global demand

[14]. This is because there are currently inadequate storage solutions for hydrogen that are inexpensive.

Solar is most likely the only source of renewable energy that could generate enough hydrogen to develop the hydrogen economy [15]. Solar is the largest source of energy, however just 0.06% of the worldwide electrical power demand is generated by solar [16]. Nevertheless, solar is projected to supply a widespread energy demand of future, hence several affordable solar energy storage technologies have been proposed to tackle the intermittency characteristic of solar energy to cover the mismatch of the supply and demand of solar power [17]. To tackle global warming and mitigate the world's dependence to fossil fuel, splitting water by solar electricity and solar-to-hydrogen technology was emerged [18]. Several solar-to-hydrogen production technologies such as thermochemical water splitting, photovoltaic-based hydrogen production, solar thermolysis, solar thermal hydrogen via electrolysis, and fossil fuels decarbonization have been proposed with special focus on the near-term sustainable methods. Concentrated photovoltaic (CPV) systems are found as one of the most affordable near-term technologies for hydrogen production with efficiency around 25% [19]. In this context, the electrolysis systems including polymer electrolyte membrane (PEM) electrolysis, alkaline water electrolysis (AWE) and solid oxide electrolysis for integrating to the solar systems for H₂ production are deployed. Among these methods, AWE has been found the most mature technique to couple with the CPV system for hydrogen production. Although, noticeable progresses have been made in solar-to-hydrogen systems, these systems need further maturation to emulate the produced grid-based hydrogen.

Compared to the other renewables, electrical power generation by wind energy has shown minimum negative impacts on the environment [20]. Approximately, 2% of global electricity demand is supplied by wind energy where USA, China, Germany, Spain, and India produce around 73% of overall worldwide wind electricity [21]. Wind-to-hydrogen using water electrolysis is another clean hydrogen production method considered by the energy policy makers. The generated electricity could be stored as hydrogen and transformed to electrical power later in times of low wind potential or when grid congestion has stopped [22]. Integrating the wind power plants to hydrogen production systems has introduced hydrogen a buffer mechanism for wind power plants to abate the intermittent characteristic of wind power [23]. Investigations about life cycle assessment of wind-to-hydrogen and hydrogen production from natural (NG) and gasoline indicate that although the cost of renewable hydrogen is

higher than non-renewable-based hydrogen production methods, using hydrogen produced by wind energy in hydrogen fuel cell vehicles instead of gasoline can lead to an economically effective mitigation of GHG emissions because the efficiency of fuel cell engines is two times more than that of an internal combustion vehicle ^[24]. The high cost of wind-to-hydrogen technology is due to the high initial cost of the installed equipment and inefficiencies in the energy conversion processes ^[25]. By integrating wind electricity to PEM, the price of hydrogen has been reported \$5.50/ kg. This price is projected to drop using advanced wind turbines and the cost target is \$2/kg ^[26].

3. Conclusion

Solar-to-hydrogen and wind-to-hydrogen offer precious benefits as a green energy carrier which made from sustainable resources of energy. Intermittency of solar / wind power is an unavoidable characteristic of these resources which could be managed by hydrogen production instead of using conventional chemical batteries. The cost of solar / wind hydrogen is dependent on the cost of solar / wind electricity. The commercialization of solar / wind-to-hydrogen is conceivable using inexpensive and robust technologies. A strong link between economy / mechanical / chemical / material sciences is needed to deploy solar / wind-to-hydrogen technologies. To expedite the commercialization of solar / wind-to-hydrogen technologies, more studies required on the wind turbines in wind electricity and the semiconductor materials in solar electricity. AWE is one of the most promising electrolysis techniques for efficient and the near-term large-scale solar / wind hydrogen production processes.

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ARTICLE

Hydrodynamic Effect on the Iso-octane Steam-Reforming in a Monolithic Reactor Channel

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ABSTRACT

The production process of clean hydrogen by iso-octane steam reforming in a micro-reactor under atmospheric pressure, and the high temperature was investigated. The simulation is done using momentum conservation, mass conservation, and convection-diffusion equations, represented by the Navier-Stokes equations, the continuity equation, and the Stefan-Maxwell equation respectively. The resolution was performed using a differential equations discretization into their conservative by the finite element method with an unconditionally stable scheme. An analysis of the hydrodynamics of the flow effect shows that the hydrogen produced by iso-octane reforming is proportional to the mixed flow Reynolds number.

1. Introduction

Hydrogen combustion releases a large amount of energy (about three times more than that of gasoline at constant weight). This combustion generates only water, which makes it an important source of clean electricity for various applications, such as supplying power in remote areas not connected to power grids. Additionally, it can be used on sensitive sites as backup energy supply. Used as a fuel cell, it allows for electricity production directly on board a vehicle driven by an electric motor with the benefit of zero CO₂ emissions. The use of hydrogen is currently almost confined to an industrial application such as ammonia production, essential for producing fertilizers, and refining oil. It is also used in other

chemical products, plastics synthesis, as well as in some glass manufacturing processes.

Despite its abundance in the universe, we can't find hydrogen in its free state. Currently, this is achieved by two main methods: decomposition of water using an electric current of fossil, nuclear, or renewable origin, or by extraction from a hydrocarbon by partial oxidation, or a reduction of the water vapor. This method consists of transforming hydrocarbons into synthetic gas by reduction with steam in the presence of a catalyst. Also called steam reforming, takes place at high temperature and moderate pressure. The method is very effective and has been extensively investigated for several years. The ethane steam reforming at a temperature of 500 °C was studied by Jens

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(Rostrup-Nielsen 1973) to determine the few factors that could impact hydrocarbon steam forming. This experiment shows that the analysis procedure is influenced by the catalyst composition, unlike the ethane hydrogen and carbon monoxide methanation of ammonia that are unaffected by the support. Garcia and Laborde^[7] carried out a thermodynamic equilibrium analysis of ethanol vapor reforming for hydrogen production, in ranges of pressure (1 - 9 atm), temperature (400-800K), and a water-ethanol ratio (0:1 - 10:1). He observed that the best condition for this process is at $T > 650$ K and under atmospheric pressure. The same process was followed by Haryanto et al.^[3] who examined different types of catalysts and observed that CO/ZnO, ZnO, Rh/Al₂O₃, Rh/CeO₂ and Ni/La₂O₃-Al₂O₃ yield good results. Yu et al. (Yu, Aihara, and Antal 1993) studied the production of hydrogen by glucose gasification in supercritical water at $T = 600$ °C and a pressure $P = 34.5$ MPa, they found that the reactor wall strongly influences the yield of this reaction. Achanbach and Riensche^[1] conducted experiments to determine the kinetics of the process of reforming methane and steam in anode materials of a fuel cell, using a catalyst that consists of 80% ZrO₂, and 20 % of Ni. This experiment was under a temperature which varies between 700 and 940 °C, a system pressure of order 1.1 to 2.8 bars, whereas that of CH₄ was from 0.11 to 0.33. Or he has proven that the partial pressure of H₂O does not influence the process of steam reforming. In order to study the kinetics of the thermal reforming reaction of liquid hydrocarbons and the performance of the used fuel processor. Methanol vapor catalytic reforming was studied as a means of generating hydrogen for a polymer electrolyte membrane fuel cell by Amphlet et al.^[4]. He developed a semi-empirical model of the kinetics of catalytic methanol steam reforming over a CuO/ZnO/Al₂O₃ catalyst. This model was capable to predict reformer performance against the various important parameters in the development of an integrated reforming polymer fuel cell system. They have found by this study that the improvement of catalyst activity and, in particular, of selectivity would be an important advantage for the optimization of the power/weight ratio of a fuel cell reformer plant intended to be used in automotive applications. A thermodynamic study of ethanol steam-reforming in a micro-reactor was carried out by Vasudeva et al. (Vasudeva et al. 1996). Adopting an approach that allows estimating the carbon formed with other gaseous species in the reforming process. Ethanol vapor, he found equilibrium hydrogen yields of up to 5.5 moles per mole of ethanol in the feed can be obtained compared to the stoichiometric value of 6.0. In order to maximize hydrogen production while discouraging reactions leading to undesirable products,

such as methane, acetaldehyde, diethyl ether or acetic acid, in competition with H₂ for hydrogen atoms. Mariño et al.^[12] carried out the procedure of steam reforming of bioethanol. The catalysts suitable for this reaction are Cu-Ni-K / γ -Al₂O₃ as they are capable of producing acceptable amounts of hydrogen operating at atmospheric pressure and at a temperature of 300 °C. It has proved that the addition of Ni to Cu /Ni/K/ γ -Al₂O₃ catalysts promotes gassing of ethanol, increases the gas yield and reduces the production of acetaldehyde and acetic acid. As the presence of Ni slightly increases the production of hydrogen by a slight increase in ethanol conversion since it promotes the segregation of Cu₂⁺ ions on the catalytic surface. Garcia et al.^[8] treated the aqueous fraction of bio-oil, resulting from the rapid pyrolysis, catalytically reformed with steam at 825 and 875 °C, a high space velocity (up to 126 000 h⁻¹) and a residence time short (26 ms), in a fixed bed microreactor interfaced with a molecular weight spectrometer. In this study, several nickel-based research and commercial catalysts were tested; these catalysts were prepared by impregnating a support α -Al₂O₃ with nickel and additives. Two strategies have been applied to improve catalyst performance. The first approach was to improve the vapor absorption to facilitate partial oxidation, i.e., the gasification of coke precursors. The second attempted to slow surface reactions leading to the formation of coke precursors due to cracking, deoxygenation and dehydration of the adsorbed intermediates. To improve steam adsorption, while cobalt and chromium additives were applied to reduce coke-forming reactions, Garcia used magnesium and lanthanum. Cobalt-activated nickel and chromium-activated nickel on MgO-La₂O₃- α -Al₂O₃ catalysts gave the best results in laboratory tests; it also observed a gradual deactivation of the catalyst under the reaction conditions. Resulting in decreased hydrogen and carbon dioxide yields and an increase in carbon monoxide. The loss of activity has also resulted in the formation of larger quantities of methane, benzene, and other aromatic compounds. He has proved by this study that commercial catalysts developed for steam reforming of natural gas and crude oil fractions have been more efficient for the production of hydrogen from bio-oil than most catalysts. research, mainly because of the greater water-gas transfer activity. Dimitris et al.^[11] investigated the catalytic performance of supported noble metal catalysts for steam reforming (SR) of ethanol in the temperature range of 600 to 850 °C with respect to the nature of the active metal phase (Rh, Ru, Pt, Pd), the nature of the support (Al₂O₃, MgO, TiO₂) and the metal filler (0-5% by weight). He found that for weakly charged catalysts, Rh is significantly more active and selective with respect to hy-

drogen formation than Ru, Pt, and Pd, which exhibit similar behavior. The catalytic performances of Rh and in particular Ru are considerably improved with the increase of the metal charge, which leads to higher ethanol conversions and hydrogen selectivities at given reaction temperatures. The catalytic activity and selectivity of the highly charged Ru catalysts are comparable to those of Rh and, therefore, ruthenium has been further investigated as a less expensive alternative. Dimitris has also proved that under certain reaction conditions, the 5% Ru/Al₂O₃ catalyst is capable of completely converting ethanol with selectivities. more than 95% hydrogen, the only by-product being methane. Pacheco et al. [14] developed a mathematical model of aspen plus process simulator, this model has been validated by an isooctane steam reforming experiment using a platinum-cerium oxide catalyst. Jeong et al. [9], studied the production of hydrogen by methanol steam reforming on Cu/Zn catalysts (Cu/ZnO, Cu/ZnO/Al₂O₃, Cu/ZnO/ZrO₂/Al₂O₃). The catalysts based on Cu/Zn are derived from precursors of the hydrotalcite type prepared by a co-precipitation process. These catalysts are characterized by measurements of N₂O chemisorption, XRD and BET surface. ZrO₂ added to the Cu/Zn catalyst improves the copper dispersion on the catalyst surface. It has proven that among the catalysts tested, Cu/ZnO/ZrO₂/Al₂O₃ has the highest methanol conversion and the lowest CO concentration in the exit gas. Adhikari et al. [2] treated Steam reforming of glycerol for the hydrogen production. The hydrogen yield of this procedure depends on several process variables, such as system pressure, temperature, and the reactants ratio. To understand the effects of these variables, Adhikari performed a thermodynamic equilibrium analysis for the glycerol Steam reforming process in the following variation ranges: pressure 1-5 atm, temperature 600-1000 K and feed ratio water-glycerol from 1:1 to 9:1. The equilibrium concentrations of different compounds were calculated by the method of direct minimization of Gibbs free energy. He found that the best conditions for the production of hydrogen are at a temperature > 900 K, at atmospheric pressure and at a water/glycerol molar ratio of 9: 1. Under these conditions, the production of methane is minimized and the Carbon formation is thermodynamically inhibited. Men et al. [13] studied the reaction between ethanol and water in the temperature range of 400 to 600 °C at atmospheric pressure and using a catalyst in a micro channel reactor. Men have found that the nature of the metal, the metal charge, and the type of media influence the catalytic activity and selectivity of the catalysts. Compared to the Co and Ni catalysts, he found that the Rh-based catalysts had the highest catalytic activity, whereas the Rh-Ni bimetallic catalysts showed a sig-

nificant improvement in terms of conversion. Ethanol and hydrogen selectivity The CeO₂-activated bimetallic Rh-Ni catalyst was stable for at least 100 hours with no detectable degradation in performance. Rabe et al. [15] analyzed the kinetics of catalytic gasoline reforming deactivation processes, the results of this modeling indicated that this reaction is strongly affected by the presence of sulfur in the alimention Du et al. [5] handled steam reforming of methanol with micro-channels. Studying the choice of catalyst, the operating parameters, and the micro-channel configuration, he found that the corresponding active Cu surface is proportional to its concentration, which improves the activity of the catalyst. The reaction temperature, the feed rate, the temperature of the mixture and the molar ratio of H₂O to CH₃OH on the conversion rate of methanol also has a significant impact. It has also been found that the increase in the length of the micro-channels can significantly improve the conversion rate of methanol. Kolb [10] provided an overview of research activities in the field of energy-using microreactors. He noted that major research efforts in this research area are currently focused on treating fuel as a source of hydrogen, primarily for distributed use through fuel cells. The development of catalysts, the reforming and removal of carbon monoxide by water-gas displacement, the design of reactors, preferential oxidation, selective methanation and membrane separation are therefore under analysis. Simsek et al. (Simsek et al. 2013) studied the steam oxidative reforming of methane to synthesis gas over an alumina supported bimetallic Pt Rh catalyst using two configurations of the coated and packed microchannel reactors. In the first geometry, thin layers of catalysts are applied to the opposite walls of a single microchannel, whereas the second geometry is described by particulate catalysts encapsulated in an empty microchannel and of the same dimensions as the first one. The two configurations are compared on the basis of methane conversion and selectivity to carbon monoxide measured at different parameters, namely reaction temperature, steam/carbon and oxygen/carbon molar ratios in feed and time of contact. They found that the coated catalyst gave CO selectivities significantly higher than the packed counterpart over the entire range of parameters. The production of clean hydrogen fuel via reformation of hydrogen sulfide in the presence of methane has been studied by El-Melih et al. [6] et al. From a small-scale reactor, the experimental results are presented on the quantities of hydrogen produced from a mixture of methane diluted in nitrogen and hydrogen sulphide at temperatures of 1273-1673 K. The results provide essential information on this method of treatment and its ability to clean hydrogen production. The experimental setup was supported by

numerical simulations in the same range of experimental conditions, helped to determine the main reaction process. Experimental results and simulation results showed a potential hydrogen recovery of more than 95% from the mixture of hydrogen sulphide and methane resulting from the destruction of hydrogen sulphide.

This work aims to study hydrogen production by iso-octane reforming with water steam via an endothermic reaction in a micro-reactor using a Ni/Al₂O₃ catalyst.

2. Method and Governing Equations

In a micro-reactor of diameter $d = 0.001$ m and length $L = 0.02$ m. The iso-octane steam reforming reaction is carried out. This requires an energy $\Delta H = 1275$ kJ/mol. Figure 1 shows the design of the studied micro-reactor.

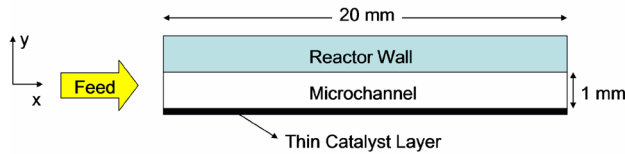
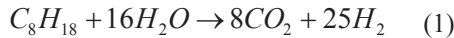


Figure 1. representative design of micro-reactor

According to the following reaction:



Considering a laminar flow, homogeneous, irrotational, and weakly compressible, the numerical study is based on a model provides the evolution of quantity of movement and conservation of mass, represented by the Navier-Stokes equations (2), and by the equation of continuity (3). On the other hand, it shows the evolution of the chemical species involved in the simulated reaction described by the diffusion-convection equations of Stefan-Maxwell (4)

$$\frac{\partial(\rho v)}{\partial t} + \nabla(\rho v \cdot v) = \nabla P + \rho g \quad (2)$$

$$\frac{\partial \rho}{\partial t} + (\rho \vec{u}) = 0 \quad (3)$$

$$\sum x_i x_j \left(\frac{J_j}{C_j} - \frac{J_i}{C_i} \right) = \frac{\nabla \mu_i}{RT} = \nabla x_i \quad (4)$$

For the turbulent flow, we used the RANS approach, based on two models; the k - ϵ model, and the k - ω model. Each model is represented by two equations: the kinetic energy equation, and the dissipation rate equation.

The k - ϵ turbulence model:

$$\rho \frac{\partial \log k}{\partial t} + \rho U \cdot \nabla k = \nabla \cdot \left[\left(\eta + \frac{\eta_T}{\sigma_k} \right) \nabla \log k \right] + \left(\eta + \frac{\eta_T}{\sigma_k} \right) (\nabla \log k)^2 + \eta_T e^{-\log k} P(U) - \frac{2}{3} \rho \nabla \cdot U - \rho e^{(\log \epsilon - \log k)} \quad (5)$$

$$\rho \frac{\partial \log \epsilon}{\partial t} + \rho U \cdot \nabla \log \epsilon = \nabla \cdot \left[\left(\eta + \frac{\eta_T}{\sigma_\epsilon} \right) \nabla \log \epsilon \right] + \left(\eta + \frac{\eta_T}{\sigma_\epsilon} \right) (\nabla \log \epsilon)^2 + C_{\epsilon 1} \left[\eta_T e^{-\log k} P(U) - \frac{2}{3} \rho \nabla \cdot U \right] - \rho C_{\epsilon 2} e^{(\log \epsilon - \log k)} \quad (6)$$

While

$$P(U) = \frac{1}{2} [\nabla u + (\nabla u)^T]^2 - \frac{2}{3} (\nabla \cdot U)^2 \quad (7)$$

Table 1. The turbulence model constants.

C_μ	Turbulent modeling constant (=0.09)
C_{d1}	Turbulent modeling constant (=1.14)
C_{d2}	Turbulent modeling constant (=1.92)
σ_k	Turbulent modeling constant (=1.00)
σ_ω	Turbulent modeling constant (=1.30)
k	Von Karman constant (=0.42)
C^+	Logarithmic wall fraction constant (=5.5)
k	Turbulent kinetic energy
ω	Turbulent dissipation rate

The k - ω turbulence model:

$$\rho \frac{\partial \log k}{\partial t} + \rho U \cdot \nabla k = \nabla \cdot \left[\left(\eta + \sigma_k \eta_T \right) \nabla \log k \right] + \left(\eta + \sigma_k \eta_T \right) (\nabla \log k)^2 + \eta_T e^{-\log k} P(U) - \frac{2}{3} \rho \nabla \cdot U - \beta_k \rho e^{\log \omega} \quad (8)$$

$$\rho \frac{\partial \log \omega}{\partial t} + \rho U \cdot \nabla \log \omega = \nabla \cdot \left[\left(\eta + \sigma_\omega \eta_T \right) \nabla \log \omega \right] + \left(\eta + \sigma_\omega \eta_T \right) (\nabla \log \omega)^2 + \alpha \left[\eta_T e^{-\log k} P(U) - \frac{2}{3} \rho \nabla \cdot U \right] - \rho \beta e^{\log \omega} \quad (9)$$

Table 2. The turbulence model constants

C_μ	Turbulent modeling constant (=0.09)
α	Turbulent modeling constant (=13/25)
β_0	Turbulent modeling constant (=9/125)
β_{0k}	Turbulent modeling constant (=0.09)
σ_ω	Turbulent modeling constant (=0.5)
k	Von Karman constant (=0.42)
C^+	Logarithmic wall fraction constant (=5.5)
k	Turbulent kinetic energy
ω	Specific Turbulent dissipation rate

The simulation was carried out with solving the differential equations in the variation form by the finite element method using an unconditionally stable (numerically) schema.

3. Results and Discussion

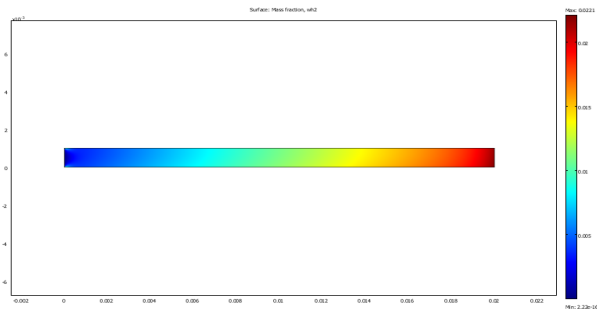


Figure 2. micro- channel simulation results

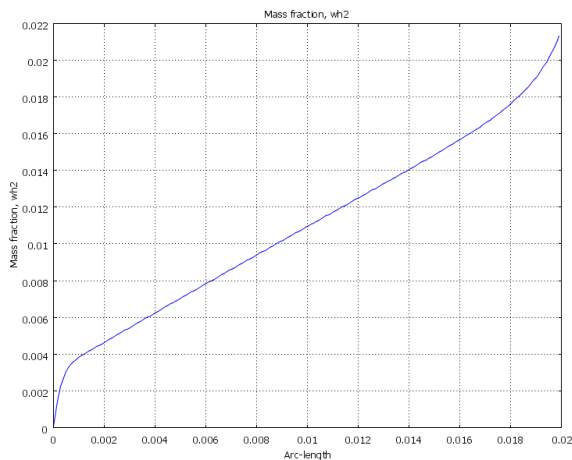


Figure 3. Mass fraction of hydrogen produce

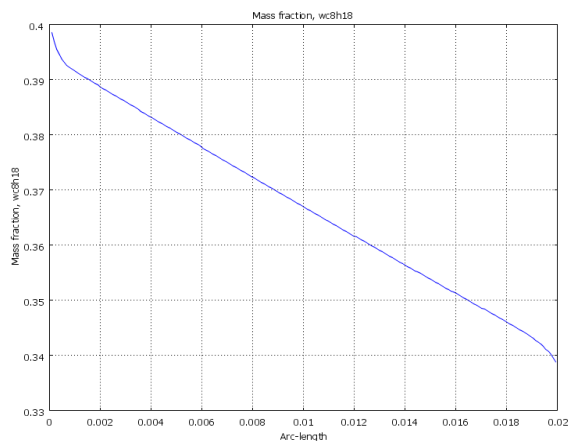


Figure 4. Mass fraction of isooctane consumed

The mass fraction of hydrogen produced, from iso-octane steam reforming reaction in a conventional micro-reactor, increases with the languor of the micro-channel where this reaction takes place, and it reaches a max: $wh2_{max} = 0.021$. This increase related to a decrease in

iso-octane mass $wc8h18_{max} = 0.339$.

3.1 Mesh Test

The mesh test was realized using a triangular form, or we tested several sizes which correspond to the different degrees of freedom and a time resolution. The following table represents the details of the test:

Table 3. the mesh test characteristics

Test Number	Number of element (-)	Number of Freedom (-)	Time resolution (s)
Test N° 01	548	7780	1.391
Test N° 02	2192	29253	2.109
Test N° 03	8768	113299	5.757
Test N° 04	35072	445791	301.091

The results obtained are represented by figure 5 and figure 6

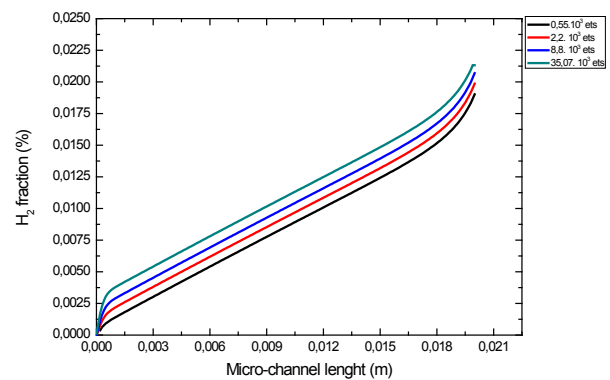


Figure 5. Mass fraction of hydrogen produce for the different mesh used

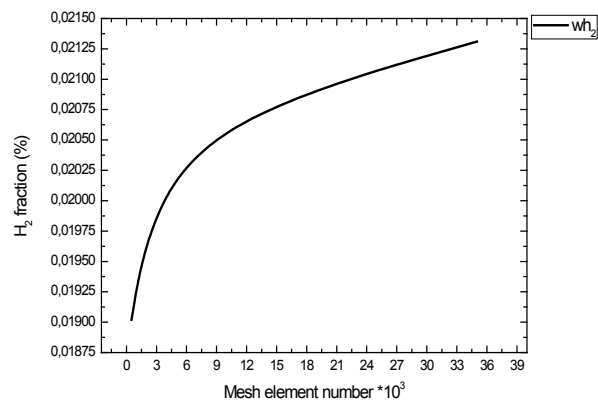


Figure 6. Mass of H_2 max produced as a function of the number of mesh element

For these different mesh, the hydrogen fraction re-

covered at the micro-channel output increases from $Wh_2 = 0.019$ using a mesh of 548 element number and 7780 freedom number, to $Wh_2 = 0.021$ for a mesh of 35072 number of elements, and a freedom number of 445791. Marking a difference of $\Delta Wh_2 = 0.002$ for a difference of 34524 element.

The following simulations, we used a triangular mesh, of 8768 number of elements.

3.2. Laminar Flow

An inertial study was conducted in order to highlight the influence of hydrodynamics on the isooctane steam reforming process. For the laminar regime, the mass of the catalyst is varied from $m = 0.01$ kg to $m = 0.9$ kg, and for each mass, we tested Somme Reynolds number, to follow the critical "Re" that characterizes it. The mass fraction of hydrogen increases with the mass of the catalyst, and it represents a saturation at $wh_2 = 1.8$. Same to the critical Reynolds number; it increases with the mass of the catalyst, to have saturation at $Re = 1900$ (Figure 8).

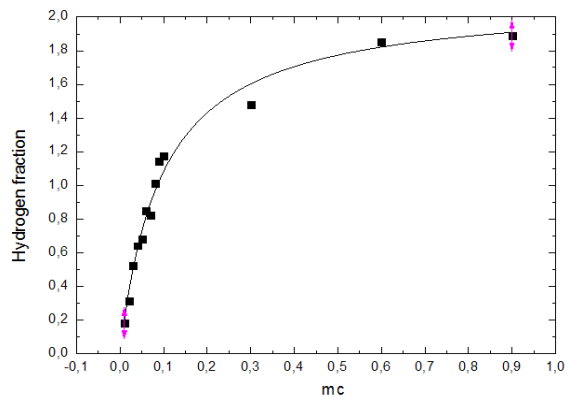


Figure 7. Mass of H_2 max produced as a function of the mass of the catalyst

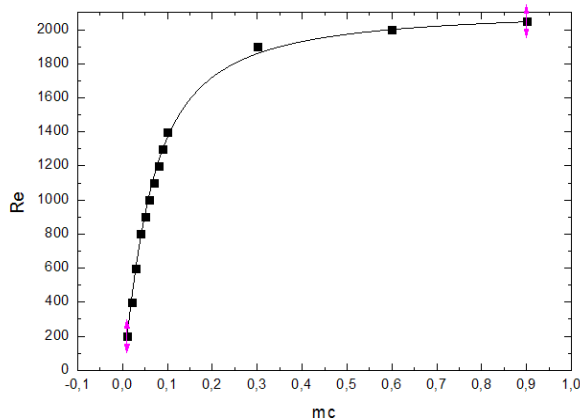


Figure 8. Critical Reynolds number for each mass of the catalyst

3.3. Turbulent Flow

Variants Reynolds number from $Re = 2000$ to $Re = 10000$ for both k- ϵ (Figure 9) and k-w (Figure 10) turbulence models. For this regime, the fraction of hydrogen increases proportionally to the Reynolds number (Figure 11), with the maxima of 1.2 for a maximum Reynolds number of 10000, that is (63,15) times higher than the reference case (laminar). Similar to the "k- ϵ " turbulence model, the hydrogen mass fraction produced increases to 1.4. Comparing the two models; we can see a difference of 20% (Figure 12)

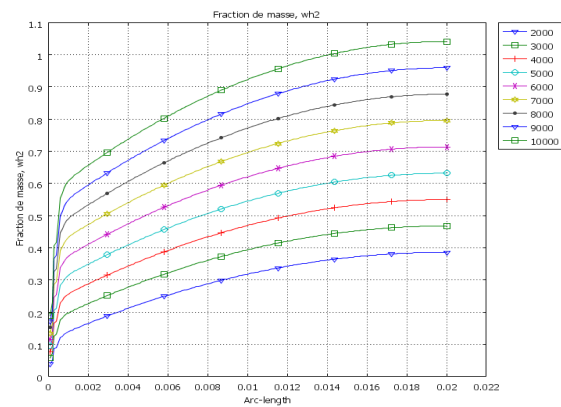


Figure 9. hydrogen mass for the different Reynolds numbers: model k- ϵ

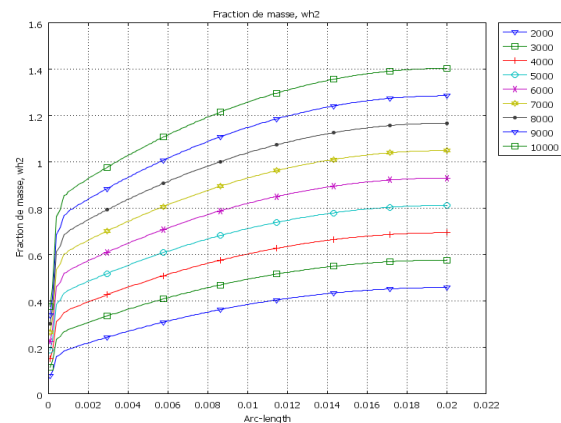


Figure 10. hydrogen mass for the different Reynolds numbers: model k-w

Table 4. Correlations

Model	equation
Turbulence k-w $Wh_2=f(Re)$	$Wh_2=0.20733+1.2 \cdot 10^{-4} \cdot Re$
Turbulence k- ϵ $Wh_2=f(Re)$	$Wh_2=0.21665+8.25 \cdot 10^{-5} \cdot Re$
Laminaire : $Rec=f(mc)$	$Rec=(2118.40758 \cdot mc^{1.25})/(0.031 \cdot mc^{1.25})$
Laminaire : $wh_2=f(mc)$	$Wh_2=(2.11025 \cdot mc)/(0.095+mc)$

4. Conclusion

Isooctane steam reforming in a micro-reactor is one of the promising processes for producing clean hydrogen. The turbulence of the flow in the micro-channel further enhances this technique. Two turbulence models have been used to simulate the iso-octane steam reforming on a monolithic reactor with a Ni/Al₂O₃ catalyst. Depending on the turbulent model the C₈H₁₈ conversion and the H₂ production vary greatly. The hydrogen fraction at the output of the micro-channel is linearly proportional to the Reynolds number; while the turbulent KW model is found to be more compatible with this technique than the K-eps.

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ARTICLE

Research on Planning and Model Design of Micro-cycle Bus Line Based on Metro Station Connection

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ABSTRACT

Public transport coverage fails to keep pace with urbanization and urban expansion, which makes the "last kilometer" problem of residents' travel increasingly prominent". However, the practice has proved that micro-circulation public transportation plays an important role in expanding the coverage of public transportation and promoting the integration of public transportation. Therefore, this paper takes a city bus community as an example. Firstly, it analyses the bus travel demand of commuters connecting to the subway station during the early workday rush hours on basis of IC Big Data, obtains candidate stations of microcirculation bus lines through K-means clustering. Secondly, it establishes the model, the target of which is to minimize the cost residents' travel and bus operation, under the limited condition of walking distance, passenger number, station spacing and departure frequency. Finally, the genetic algorithm is used to find the optimal solution of the model, so it's no doubt that the most feasible circular bus route is obtained. The results have positive significance for promoting the construction and operation of public transport integration and promoting the convenience and efficiency of public transport travel.

1. Introduction

With the rapid development of urbanization and the continuous expansion of urban areas, more and more urban residential areas or active areas are far away from public transport stations such as buses and metros. Research has proved that "the increasing speed of traffic demand is always faster than the speed of the reconstruction and expansion of municipal roads", and the existing coverage of public transport has not yet fully met the needs of public transport travel. Therefore, in order to solve the "last kilometer" problem of residents' travel, many cities, including Guangzhou and Shenzhen, have opened microcirculation buses with

the main purpose and function of "connecting urban rail transit" and "filling the gap of branch bus network". Microcirculation bus, also known as "pocket bus", is called the capillary of public transport. It has the characteristics of small vehicle type, agility, few stations, short distance, fast speed and concentrated passenger flow distribution. It can not only realize the effective series connection of community, school, vegetable market, hospital, bus station and subway station in the region, but also promote the convenience and efficiency of public transport travel. It can also play the role of efficient connection and rapid distribution of passenger flow at stations, and promote the construction and operation of public transport integration.

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2. The Current Research

There are plenty of achievements in the study of microcirculation bus route planning, design and optimization model at home and abroad. In terms of relevant research results abroad, Kuah (1987) established a model to determine the route direction and frequency of community bus fleet based on the fleet size under the assumption that "passengers start from multiple starting points and destination transfer stations are the same", and found that the model is also applicable to the "multi-to-many" demand model^[1]; Nagm-chai and Lovell (2003) are based on passengers and buses. Total cost minimization is used to study the optimization of bus route design^[2]. The genetic algorithm is used to generate the bus route and evaluate the bus route. Avishai Ceder (2010) proposes a new method of bus route design in the circle community, which quantifies the potential population in the community to the community road, so as to maximize the potential bus passenger flow^[3]. In terms of domestic related research results, Zhang Silin (2016) takes into account both resident travel costs and bus operation costs, and constructs a research model for bus station layout in urban rail transit community with constraints of walking distance, full load rate, departure frequency and station spacing, and verifies the rationality of the model through genetic algorithm^[4]; Xie Chao and Wang Anqi (2016) in vehicle purchase costs, and bus operation costs. In the absence of time-division multiplexing of bus parking lots and other reasons that make microcirculation lines difficult to play an ideal role, an optimization scheme of regional microcirculation bus system, including the introduction of small and medium-sized new energy buses, is proposed. The scheme is not only effective and feasible, but also can improve the operation efficiency of microcirculation bus system and reduce the operation cost^[5]. Zhou Jin (2016) is based on double-deck theory and genetic algorithm. Method: Starting from the interests of both bus and passengers, a minibus route direction model is constructed under the constraints of bus route length, non-linear coefficient, departure frequency and bus stops, and the feasibility of the model is verified by taking Tiantongyuan community in Beijing as an example^[6]. Lu Qianjie et al. (2016) constructed an ant colony algorithm for the phenomenon of multiple passengers going to different terminals at different starting points in the system. A path planning algorithm for multi-start and multi-end problem is presented. The feasibility of applying this algorithm to community public transport system is verified by community measurement^[7]. Zhou Xiangdong (2017) introduces the concept of microcirculation bus under block system, takes passenger time demand as the main constraint, builds a microcirculation bus route design model aiming at minimizing enterprise cost, and uses ge-

netic algorithm to solve it. The feasibility and applicability of the solution and validation of the model and algorithm; Li Fei et al. (2018) based on the summary of experience in the planning of microcirculatory public transport network and the characteristics of positioning service, applied the big data of public transport to study and analyze the weak areas and hot areas covered by public transport in Long-gang District of Shenzhen, and to determine the direction of short-distance travel demand, providing data support for the planning and improvement of microcirculatory public transport^[8].

At home and abroad, a large number of studies have been carried out on the design and optimization model and algorithm of microcirculation bus route planning. The theoretical scientificity and practical feasibility of the research results have been verified by examples, but relatively few studies have been carried out on the basis of community commuters' travel needs and the promotion of bus integration. Based on IC card data, this paper identifies the commuter's demand analysis of getting up and down bus station, analyzing passenger flow direction, selecting hot demand station area and so on, and then obtains the candidate bus station by cluster analysis. Then, a microcirculation bus route planning and design model is constructed by minimizing passenger travel cost and bus operation cost, and genetic algorithm is used. The most feasible route operation scheme is obtained.

3. Data Acquisition and Processing

3.1 Data Acquisition

The data used in this study are from IC card data of a city. In order to exclude the influence of holiday factors, the time range of data acquisition is set to November 2018. The main data acquisition contents are bus IC card swipe data (shown in Table 1), bus GPS data (shown in Table 2) and site GIS data.

Table 1. The structure of bus IC card data

Card_id	Deal_time	Deal_amt (¥)	Card_type	Terminal_id	Line_name
510000*****2800	20171116073300	1.2	IC Card	05065000	A
510000*****8640	20171116081522	1.2	IC Card	06800410	B
510000*****2870	20171116220506	2	IC Card	01110612	C

Table 2. The structure of bus GPS data

Time	V _{GPS}	GPSTerminal_id	Line_name	longitude	latitude
20171116081448	5.22	11071103	A	113.5025	23.17637
20171116175502	3.55	11062302	B	113.5314	23.14928
20171113092229	4.54	11059604	C	113.4732	23.17841

3.2 Data Acquisition and Processing

In order to improve the efficiency and accuracy of data analysis and effectively avoid the interference of incomplete data, redundant data, noise data, error data and other abnormal data, it is necessary to carry out pre-processing work such as cleaning, fusion, transformation and reduction of bus IC card swipe data and bus GPS data. After data pretreatment, more than 94 million effective bus IC card consumption data meet the data quality and application requirements, and more than 9,000 bus-operated vehicles correspondingly. There are 332 bus routes that meet the requirements of bus IC card consumption data and bus GPS data integrity. In addition, because this paper takes commuters as the research object, this paper adopts Chen Jun's definition of commuters in 2018: "The total number of first commuters in the peak period of a week is greater than or equal to six times, the total number of first commuters in the peak period and the total number of first commuters in the evening peak are greater than two times", and the non-commuters are excluded.

4. Bus Travel Demand Analysis and Route Planning

This paper establishes a public transport community within 3 kilometers of a large community bus station in a city, and studies the transit demand of commuters in the community and the planning of microcirculation circular bus lines.

4.1 Travel Demand Analysis of Micro-cycle Bus Connecting with Metro Station

4.1.1 Recognition of the Upper and Lower Station Points of Bus Travel Starting from Xiangxue Metro Station

Recognition of boarding station points: (1) Select the swipe card data of an IC card on the working day, rank them according to the transaction time, and regard the subway station where the second swipe card happened on the same day as the transfer station; (2) Select the bus GPS trajectory point closest to the GIS location of the transfer station as the bus entry station; (3) Analyse the similarity of the bus trajectory to identify the actual route of the vehicle, and recognize the spatio-temporal variation of the continuous GPS points. The arrival time of vehicles is calculated by using the speed information data recorded by GPS. (4) The arrival time of passengers is matched with the arrival time of vehicles. The nearest arrival time is chosen as the boarding time, and the corresponding station of GPS is the boarding point.

Recognition of disembarkation points: Bus lines usually adopt the "one ticket" system, swiping cards only when boarding, and no second swiping cards when disembarking. That is to say, IC cards have no record of disembarkation swiping cards, so it is necessary to infer the disembarkation points of passengers according to the results of identification of passengers' boarding points. Referring to Hu Jihua et al. (2017) based on the inference method of travel chain, this paper infers that the bus departure point^[9], which connects the bus departure points above the station points on the same day as the departure and departure points, can form a closed-loop travel chain. Because most of the commuter's routes are the same, the bus departure points in the evening rush hour are the early rush bus departure stations. Point.

4.1.2 Recognition of Bus Departure and Departure Points Based on Xiangxue Metro Station

Recognition of boarding station: (1) Select the data of IC card swiping on working day, read one card data in turn according to the order of transaction time, judge whether it is the first time to swipe card, if not the first time to swipe card, then delete the data; (2) analyze the bus GPS trajectory point closest to the bus station as the entry station; (3) Analyse the similarity of bus line trajectory to identify the actual route of the vehicle, and base it on the analysis of the similarity of bus line trajectory. Vehicle arrival time is calculated by using the speed information data recorded by GPS. (4) The arrival time of passengers is matched with the arrival time of vehicles. The nearest arrival time is chosen as the boarding time, and the corresponding station of GPS is the boarding point.

Recognition of disembarkation point: Passengers generate IC card transaction data when they transfer to the subway, and match the IC card information of the first Metro trip on that day with that of the bus trip on the station. If the card number is the same, the bus station nearest to the GIS location of the subway station will be selected as the disembarkation point.

4.2 Passenger Flow Analysis and Regional Identification of Popular Demand Sites

Passenger flow direction and travel demand are the premise and basis of the planning and design of microcirculation bus line and the key to the opening of the line. On the basis of identifying the starting and ending points of the subway station, the flow direction of passenger flow is analyzed and the corresponding passenger flow is counted. The station area with 100 passengers or more on or off the early peak is selected as the hot demand station area, and

then the conclusion is drawn. The main passenger flow direction starting from Xiangxue Metro Station and the main passenger flow source starting from Xiangxue Metro Station (as shown in Table 3).

Table 3. The travel demand of main hot sites at early Peak

Sites	The passenger flow form Xiangxue Metro Station	The passenger flow to Xiangxue Metro Station
Huochun	53	117
Kaiyuan Avenue	47	114
Huapu Village	38	126
Yangcheng School	43	137
Yuyan Road	41	113
Hecun	35	102
Xiangxue Apartment	113	39
Luogang Village	101	46
Jeep Electronics	115	35
Liucun	106	30
Development Zone	118	37

In the early peak period, the passenger flow with Xiangxue Metro Station as the terminal point mainly comes from six areas, namely Huochun, Kaiyuan Avenue, Huapu Village, Yangcheng School, Yuyan Road, Hecun. The main residential areas in the above areas are Xiangxue Apartment, Luogang Village, Jeep Electronics, Liucun and Development Zone. Industrial parks and other five regions, the above areas are mainly commercial and industrial parks.

4.3 Bus Travel Station Clustering Analysis

On the basis of identifying nine hotspot demand sites, K-means method is used to cluster the similar travel demand sites in these regions. The specific steps are as follows:

(1) Suppose that i sample set $\{X_i, i=1,2,\dots,N, i \in Z\}$ classifies the data points in the sample set into K clustering centers $Z_k, K=\{1,2,\dots,N, k \in Z\}$ in the corresponding category;

(2) Calculate the sum of squares of distances from similar data points to cluster centers, select the cluster centers with the smallest distances, and classify the corresponding travel demand sites into clusters C_k ;

(3) Update the demand points in each cluster, calculate the average value of each cluster and use it as the new cluster center Z_{k1} ;

(4) According to formula (1), the sum of squares of in-

tra-class errors is calculated.

$$E = \sum_{i=1}^n \sum_{p \in C_k} \|p - z_k'\|^2 \quad (1)$$

Among them, P is the demand point in the cluster C_k and the Z_k is new demand point in the cluster C_k .

(5) The E value is calculated iteratively for several times, and when the change of E value stops or is not large, the operation is terminated; otherwise, the steps (3) to (5) are repeated.

In this paper, the maximum walking distance threshold of passengers is 500 m, and the existing station with the largest passenger flow near the cluster center is the micro-circulation bus stop, which can not only ensure the fine-grained bus passengers, but also avoid the cost investment of new stations. According to the clustering results, eight candidate stations, including Xiangxue Apartment (49), Luogang Village (11), Yuyan Road (34), Yangcheng School (7), Liucun (4), Hecun (63), Jiepu Electronics, (21) and Development Zone (40), were obtained to construct microcirculation bus loop.

5 Model Setting and Analysis

5.1 Model Setting

Based on the principle of "minimizing the total cost of passenger travel and bus operation", this paper aims to build the model as follows:

(1) The operation cost of microcirculation bus consists (C_b) of the vehicle operation cost and labor cost generated during the operation of bus. Assuming that the bus runs at a uniform speed, the running cost of the bus can be measured by the running time of the bus, and the labor cost can also be measured by the working time. Then the minimization function of the operation cost of the circular bus is set as follows:

$$C_b = C_m V_e \sum_{i \in S} \sum_{j \in SU} \sum_{k \in K} t_{ij} y_{ijk} + C_n \sum_{i \in S} \sum_{j \in SU} \sum_{k \in K} t_{ij} y_{ijk}$$

Among them: S stands for bus station; S_0 stands for bus station; K stands for bus $k \in K$; C_m stands for operation cost per kilometer, including fuel consumption cost and bus maintenance cost; C_n indicates labor cost per hour; V_b indicates vehicle speed; t_{ij} indicates average travel time of bus station i and j ; y_{ijk} is 0-1 decision variable, if the next bus station K is j after visiting bus station i , Set a value of 1, otherwise 0.

(2) Passenger travel cost (C_p) of walking time, waiting time and on-the-way time and fare of passengers from the original station to the station. Then the passenger travel cost function is set as follows:

Among them: S_1 expressing the original station point; S_{s1}^i expressing the number of passengers boarding at station i ; V_b expressing the value of travel unit time; expressing the cost of walking time, V_{bt_b} expressing walking time; t_b expressing the cost of waiting time, $V_b \frac{1}{2}$ assuming that waiting time is 1/2 of departure interval (h); $V_{bt_{ij}}$ expressing the cost of on-the-way time, t_{ij} expressing the travel time from station i to station j ; f expressing the bus fare.

(3) Path optimization model and constraints

$$MINC = MIN \{ \alpha C_b + (1 - \alpha) C_p \}$$

$$S.T. \begin{cases} L_{S1} \leq L_b \\ M \leq \sum Q_{ij} \leq M_{\max} \\ L_{\min} \leq L_{ij} \leq L_{\max} \\ F_{\min} \leq F \leq F_{\max} \end{cases}$$

Among them: and $1-\alpha$ the weight coefficients of two objective functions are expressed separately; L_b expressing the maximum walking distance, L_{S1} is expressed as the walking distance from the original station to the waiting station; $\sum Q_{ij}$ expressing the number of micro-cycle bus passengers from station i to station j , M is expressed as the number of bus seats, $M_{\max}$ representing the maximum number of passengers; L_{ij} is expressed the station spacing between station i and station j , $L_{\min}$ and $L_{\max}$ are expressed as the minimum and maximum station spacing between station i and station j respectively; F expressing departure frequency, $F_{\min}$ and $F_{\max}$ respectively expressing minimum departure frequency and maximum departure frequency..

5.2 Model Analysis

5.2.1 Overview of Algorithms

Genetic Algorithms (GA) is a common intelligent algorithm for solving multiple feasible solutions, which has the characteristics of "directly using the objective function as search information; inherent parallelism; and adaptive search", and can be applied to the study of optimal solutions. Therefore, this paper uses GA algorithm to study the minimization of passenger travel and bus operation costs in micro-cycle bus route planning. The algorithm process is as follows:

(1) Setting initialization parameters. When the number of public transport is a , the input parameters are: population size N , crossover probability P_c and mutation rate P_m .

(2) Initial line generation. Based on the coding rule of 0-1 variable, the number of chromosomes of the population is generated randomly, that is to say, the initial line is

obtained.

(3) Calculate the fitness function. Fitness function is $G = \alpha C_b + (1 - \alpha) C_p + \sum_{i=1}^4 p_i$, in which: p_i for penalty items, including walking distance penalty items p_1 , passenger number penalty items p_2 , station spacing penalty items p_3 , departure frequency penalty items p_4 . The fitness function was calculated and the population was sorted according to the size, and the chromosomes with higher fitness were evolved into the next generation population.

(4) Cross-variation. The new generation of chromosomes can be obtained by random pairing and crossover of the evolutionary chromosomes.

(5) Check the number of iterations. When the number of iterations reaches the maximum number of iterations, at the end of the iteration, the optimal value and chromosome can be output, that is, the bus line and its station can be obtained, otherwise step 4 will be returned.

(6) Scheme comparison. The scheme with the minimum objective function value is chosen as the optimal scheme.

5.2.2 Model Computation

(1) Parameter Setting

Assuming that the number of microcirculatory buses is 6, the optimal solution is obtained when the input parameters are based on Visual C++ 6.0 platform: Max GEN is 50, population size N is 40, crossover probability is 0.6 and mutation rate p_m is 0.1. At the same time, set the following parameters, as shown in Table 4.

Table 4. Parameter Settings

NO.	Parametric Item	Parametric Value	NO.	Parametric Item	Parametric Value
1	C_n	49¥/h	9	$F_{\max}$	16times/h
2	V_b	20¥/h	10	$L_{\max}$	4km
4	L_b	500m	12	p_1	1000
5	V_e	300m/min	13	p_2	1000
6	C_b	2.5¥/km	14	p_3	1000
7	$M_{\max}$	30	15	α	0.4
8	$F_{\min}$	4times/h			

(2) Operational Results

As shown in Figure 5, according to the current road traffic conditions, this paper proposes to establish micro-cycle bus routes connecting the above eight candidate stations with the subway stations. According to the different running directions, the clockwise (Plan A) and anticlockwise route (Plan B) schemes are formulated, and the genetic algorithm is used to optimize the route schemes.

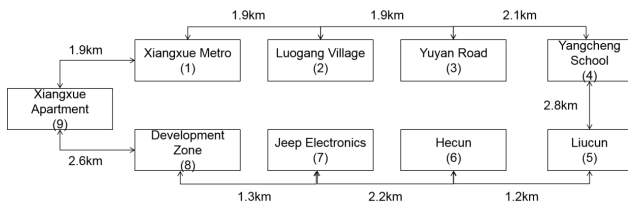


Figure 5. The guess of operation route of Microcirculation Bus

As shown in Table 5, after optimization, the passenger travel cost C_p , bus operation cost C_b and target cost C_t of microcirculation bus clockwise operation decreased by 5057 yuan, 383 yuan and 3187.4 yuan, respectively, compared with those before optimization, with the decreases of 28.36%, 20.88% and 2.86%, respectively. This shows that the model is effective in optimizing the layout of line stations and reducing the cost of passenger travel and bus operation.

Table 5. The cost comparison before and after optimization of clockwise operation route of Microcirculation Bus

Plan	Station line	Optimized state	C_p (¥)	C_b (¥)	C_t (¥)
A	(1)–(2)–(3)–(4)–(5)–(6)–(7)–(8)–(9)–(1)	before	17832	1834	11432.8
	(1)–(3)–(4)–(5)–(7)–(9)–(1)	after	12775	1451	8245.4

Furthermore, as shown in Table 6, after optimization, the passenger travel cost, bus operation cost and target cost of microcirculation bus are reduced by 5347 yuan, 407 yuan and 3371 yuan respectively, with a decrease of 29.99%, 22.19% and 3.03% respectively, which also shows the effectiveness of the model in optimizing the layout of line stations and reducing the cost of passenger travel and bus operation.

Table 6. The cost comparison before and after optimization of counter-clockwise operation route of Microcirculation Bus

Plan	Station line	Optimized state	C_p (¥)	C_b (¥)	C_t (¥)
B	(1)–(9)–(8)–(7)–(6)–(5)–(4)–(3)–(2)–(1)	before	17416	1829	11181.2
	(1)–(8)–(6)–(4)–(3)–(1)	after	12069	1422	7810.2

Finally, since the target cost of the optimized anti-clockwise route scheme is lower than that of the clockwise route scheme, the anti-clockwise route scheme of the micro-circulation bus is more feasible according to the

principle of minimizing the total cost of passenger travel and bus operation.

6. Conclusion

Based on IC data of a city, this paper uses IC card data, identifies commuters' needs of getting up and down bus stops, analyses passenger flow direction, and chooses popular demand stops area, and then obtains eight candidate bus stops by clustering analysis. It establishes the goal of minimizing the sum of resident travel cost and bus operation cost, and takes walking distance as the goal. The optimization model of microcirculation bus line with the constraints of passenger number, station spacing and departure frequency is presented. According to the difference between the current road traffic situation and the direction of bus operation, the optimal solution of microcirculation bus line optimization model is obtained by using genetic algorithm on the platform of Visual C++ 6.0, and the optimal microcirculation bus line connecting rail transit according to the objective function and constraints is obtained. The validity of the model is illustrated, which has a positive significance for guiding the planning and design of microcirculation bus routes and promoting the development of public transport integration.

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ARTICLE

Discussion on Quality Control Mode of Internet + Greening Maintenance

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ABSTRACT

With the rapid increase of the construction volume of our country's landscape industry, the scale of the stock gardens is getting larger and larger. Later gardening maintenance technology needs to be constantly updated, and management modes and methods should be constantly innovated to meet the development needs of the maintenance market. The quality of maintenance and management in the later stage of green space construction is intuitively presented to the viewers through the quality of landscape. Therefore, improving the quality control ability of green space is the most important thing for the rapid development of garden enterprises. This paper combines the Internet with traditional maintenance quality management through Internet thinking, and achieves several important points in quality control, such as planning, traces, inspection, reporting and customer service evaluation, on the Internet management and control platform. Among them, the work plan combined with the maintenance calendar, the climate and soil and other environmental data from all parts of the country can better guide the field work; Maintenance trace record can provide data feedback through pictures, videos, etc.; Patrol function discovers green space problems in time, records data of basic problems of green space and feedback processing; And reporting function can provide customers with more convenient maintenance services. The addition of customer evaluation forms an important closed-loop for staff management and site quality from the perspective of customers. To some extent, this study solved the problems of insufficient quality standards and low efficiency under the traditional maintenance management mode, which accords with people's service demand for greening maintenance at the present stage, and helps to enhance people's recognition of greening personnel. With the help of Internet management and control thinking, we can better solve the pain points existing in the development of maintenance enterprises, provide new tools for the better development of maintenance industry, and lay a foundation for the growth of maintenance industry.

1.Introduction

In recent years, with the rapid increase of the construction area of green space in our country, people pay more attention to urban green space, and at the same

time, the national requirements for the quality of urban green space are constantly improving. Landscape conservation has changed from a traditional agriculture and forestry industry to a service-oriented tertiary industry.^[1]

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The market-oriented level of greening and maintenance in China is low, and the quality of greening and maintenance is declining year by year with the development of the industry. With the trend of "Internet +" sweeping all industries, the development of landscape quality management also has an opportunity.

2. The Pain Point of Maintenance Industry

2.1 Greening and Maintenance Enterprises are Uneven in Good and Bad

At present, most of the greening and maintenance enterprises are landscape construction enterprises, and a few enterprises rely on the construction team for greening and maintenance. Therefore, it is difficult to recruit the ideal greening maintenance enterprises in the tender of greening maintenance management projects, which is also an important reason why it is difficult to promote the marketization of the industry.^[2]

2.2 The Level of Maintenance Team is Declining

Horticultural practice requires the accumulation of experience and the succession of professional horticultural workers from generation to generation. Nowadays, in order to save costs, most social enterprises seldom maintain a fixed maintenance workforce. Many enterprises directly recruit temporary workers and migrant workers from the labor market when their business is busy, and undergo simple training. After that, they began to engage in maintenance work, which resulted in lack of pertinence and technicality in specific operations. Considering the cost, most of the recruited workers are the elderly, infirm or women with low wages. They can only do simple work with low technical content, such as pruning, weeding, watering and fertilization. The quality of maintenance is difficult to guarantee, and there is no way to elaborate and artistic.^[3,5]

2.3 the Quality of Landscape Declines

The poor management and control level of maintenance enterprises and the low technical level of maintenance workers lead to the poor effect of landscape presentation. Landscape quality of garden green space does not show a benign development with the development of marketization, on the contrary, it shows a downward trend, which is also a major obstacle in the process of marketization of maintenance industry.^[4]

3. Requirements for Quality Management of Greening Maintenance

Quality management in gardening maintenance is the

basis for the healthy development of gardening industry. Maintenance quality control needs to start from the following four aspects: (1) Formulate the maintenance plan and record the traces of implementation in order to facilitate the retrospective analysis of the later green space problems; (2) Regularly inspect the maintenance of green space, deal with the green space problems at an early stage, and avoid the expansion of the problems. At the same time, the occurrence of diseases and plant growth were recorded to provide reference for later maintenance managers. (3) Timely communication with customers to understand their higher service needs and solve the green space maintenance problems on important nodes; (4) Customers participate in the monthly maintenance effect satisfaction evaluation.

4. Internet + Green Maintenance Quality Control

According to the requirement of garden maintenance management, the intelligent greening maintenance platform is built with the help of mobile Internet technology, Internet of Things sensor technology, large data precision analysis technology and plant management technology, and the intelligent service mode of greening maintenance is formed^[6], which involves community green space, park green space, road green space, orchard, intelligent farm and shelter forest. Maintenance services of green space such as reserve forest and industrial green space.^[3] According to the market-oriented trend of greening maintenance, the platform provides professional services for the management and maintenance of national green space after construction; Relying on advanced domestic mobile interconnection technology and environment, it combines the core points of traditional maintenance management and control with the fast professional service requirements under the new situation, and make systems, such as mobile devices, computer rooms, sensors, positioning, regulation and control, to be integrated to achieve fast connection; Relying on greening and maintenance technology, we can provide professional services to government greening supervision units, property customers, maintenance industry enterprises and individual users.^[7]

In terms of quality control, the garden maintenance platform achieves effective quality management through the following methods:

(1) Planning Control

According to the experience of traditional gardens maintenance, the calendar of gardens maintenance is sorted out as Table 1. Landscape maintenance platform relies on the Internet of Things technology. Through the

maintenance of calendar and environmental information of green space, the plan of landscape maintenance is formulated. The environmental information includes meteorological information of the location of the garden, data information of soil temperature, humidity and fertility in plant growth environment, etc. These information are fed back to the garden maintenance platform by sensors, and then to make more elaborate, more scientific and more appropriate garden maintenance plan. At the same time, through the transmission unit, the garden maintenance plan is sent to the corresponding maintenance workers, and the image information of the key maintenance points is acquired in real time. By comparing the operation standards stored in the unit and server, the standardization and information management of gardens can be realized, and a new scientific basis for gardens maintenance can be formed. The efficiency and scope of management and control can be improved to meet the needs of market-oriented gardens maintenance.

Table 1. Monthly Plan for Garden Maintenance

Month	Solar Term	Phenological Characteristics	Key Work and Nodes
January	Great Cold, Slight Cold	Dormancy	Tree pruning
February	Beginning of Spring, Rain Water	Dormancy,	Tree pruning, water replenishment, disease and pest control
March	Insects Awakening, Spring Equinox	Avoid falling Spring Cold	Returning green water irrigation, disease and pest control, greenbelt sanitation
April	Fresh Green, Grain Rain	Growing period	Tillering bud removal, Pruning after Flowering, Disease and Pest Control, Watering
May	Beginning of Summer, Lesser Fullness	Growing period	Water supplement, post-flowering pruning, disease and pest control
June	Grain in Ear, Summer Solstice	High temperature, coke leaf	Supplementary water, disease and pest control, dedium tillage and weeding
July	Lesser Heat, Greater Heat	High temperature and wetness, weeds	Drainage, disease and pest control, medium tillage and weeding
August	Beginning of Autumn, End of Heat	High temperature and humidity	Waterlogging, disease and pest control, dedium tillage and weeding
September	White Dew, Autumnal Equinox	Cooling and drying,	Fertilizing, disease and pest control
October	Cold Dew, First Frost	Plants entering dormancy period	Fertilize and keep green space clean
November	Beginning of Winter, Light Snow	Plants enter dormancy period.	Winter irrigation and cold protection
December	Heavy Snow, Winter Solstice	Plant dormancy	Pruning and pest control

(2) Trace Management

Maintenance log is very important in the process of traditional maintenance work. When problems arise in the maintenance of green space, it can be traced back to the source in time. In this paper, the maintenance work is redefined and classified into the following categories and sub-items, such as Table 2.

Table 2. Maintenance Work Items

Number	Category of Work	Subitem of Work
1	Irrigation and drainage management	Drainage
2	Fertilization management	Fertilization of lawn, shrub and tree, rejuvenation of lawn and big tree
3	Pruning management	lawn, ball, hedge, flower and shrub, tree pruning
4	Medium tillage, weeding	Weir repair, lawn trimming, weeding, tillering
5	Plant Protection Management	Control of underground diseases and insects, dry-borers and leaf diseases and insects
6	Clean management of green space	Defoliation and other garbage disposal
7	Planting management	Lawn sowing, lawn planting, perennial root flowers and seedlings planting
8	Cold-proof management	white coating, dry wrapping and cold-proof barrier erection
9	Bright Spots	Festival dresses, flowers rent
10	Facilities Maintenance	Landscape sketches maintenance, landscape architecture maintenance

Maintenance worker receives the maintenance work plan sent by the garden maintenance platform, carries out maintenance work according to the planned time node, and uploads maintenance information in time, including work items, number, location, time and completion effect. The platform can obtain the mobile track of the workers' mobile terminal in time, and the workers' mobile terminal can be pre-loaded in the green space. Real-time gardening information based on geographic location feedback. The platform judges whether the garden maintenance plan has been completed on time according to the information of the completion of maintenance. If it is not completed on time, it will warn in time.

(3) Maintenance patrol

Through the patrol of green space maintenance, the platform can timely detect pests, weeds, garbage and other diseases in green space, and deal with them, so as to avoid the expansion of the problem. At the same time, the record of inspection results can also play a guiding role in the maintenance and management of the next year.

According to the patrol route, maintenance key points are pre-set, and maintenance managers can patrol many key points in the garden. Maintenance managers regularly patrol several fixed patrol routes set up on the spot, and

record the trajectory by terminal during the patrol, and take photos at key points to record the growth of lawns, shrubs and trees. The photos can be uploaded as real-time garden information. The real-time plant images taken by maintenance workers were compared with the preset images, and the circumstances of growth and development of plants were analyzed by plant analysis system.

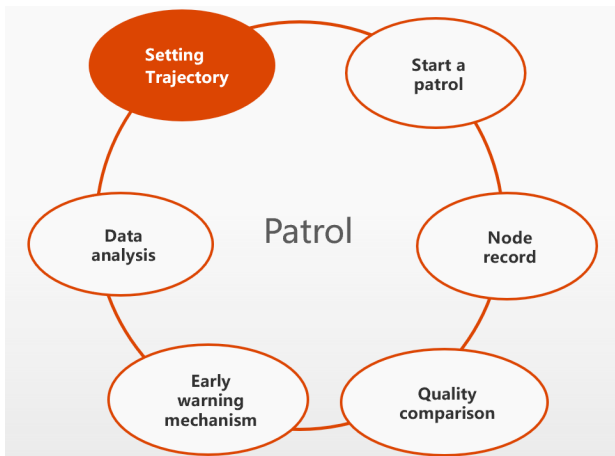


Figure 1. Landscape Maintenance Platform Patrol Workflow

(4) The Incident Reporting System

As people pay more and more attention to the green space, the demand for the service of maintenance practitioners is also increasing. The service can be more convenient through the garden maintenance platform. The specific process is shown in Figure 2 below.

Customers and tourists feedback some green space problems to maintenance workers through the platform, and maintenance workers confirm and disposal. After the report processing is completed, the maintenance workers can take the video or pictures after processing, and feedback them to customers and tourists for confirmation. Customers and tourists can evaluate and feedback this information.



Figure 2. The Incident Reporting System Workflow of Landscape Maintenance Platform

(5) Customer Evaluation System

In the green space maintenance service, the customer's suggestion is the key indicator of service quality. The garden maintenance platform includes the customer evaluation, investigation and analysis function. Specific concerns are shown in tables 3 below.

Set different maintenance scoring tables according to different seasons, and send them to the customer's scoring terminal to get the score. After obtaining several gardens' maintenance scoring tables, through statistical processing of these maintenance scoring tables, we can get the overall situation of gardens' maintenance, and can adjust the gardens' maintenance nursing strategy accordingly.

Table 3. Questionnaire Evaluation and Analysis Items

Serial Number	Specific Contents of the Survey
1	Feedback on the implementation of the questionnaire item in the Satisfaction Survey last month
2	Timeliness/completeness of submission of monthly/weekly work plan
3	Implementation and completion of key/node work this month
4	Standardized management
5	Initiative of daily operations employees
6	Grass-roots managers' ability to communicate and solve problems actively
7	Customer's comments and requests for timely feedback
8	Overall effect of green space maintenance

5. Internet + Mode Changes the Results

Through the development of Internet management and control software, the combination of green space maintenance and management and the Internet has made a fundamental change in the traditional mode of green space maintenance and control^[8]. The traditional management mode depends on the person in charge of the site, and the managers with insufficient technology and management ability will cause the quality of the site to decline seriously. And through detailed planning and feedback implementation, process standardization, then the site quality will be effectively guaranteed. At the same time, the former extensive management will be changed to fine management, so that the field work will be service-oriented and become more humane.^[9,10]

6. Conclusion

Maintenance work combined with the Internet can make greening maintenance more standardized and refined. Only by constantly applying new tools to the maintenance work, can we maintain the youth vitality of the

maintenance work and promote the healthy development of the maintenance industry.^[11]

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REVIEW

Airport Revenue Diversification

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ABSTRACT

This report emphasizes the non-aeronautical revenues of airports that are playing an increasingly important part in the revenues of airport. This report delves into different fields of non-aeronautical services that serve as an important revenue source as well as how to better manage these fields to bring greater profits and incomes for the airport. This report focuses on airport advertising, food and beverage and airport car parking as to their potential benefits and threats to the revenues of different airports. It shows that although these fields of non-aeronautical services can potentially bring in a lot of revenues and profits to the airports, different airports also need to adopt proactive policies and strategies to improve these fields to increase their revenues and competitiveness.

1. Introduction

Airport not only serves as a transportation hub for commercial aircrafts or cargo aircrafts, but also has important economic, social, political and military implications and significance. Leva et al.^[1] (2014) argue that airports play an important part in air transport system and are important to increase “the quality of life of regional and local communities, directly participating in wealth creation”. It is well known that the major purpose and function of airport is for aeronautical purpose for different airlines, commercial airlines and cargo airlines. However, it should be noted that the non-aeronautical revenues are also important sources of revenues for airports, which is playing an increasingly important part of the

revenues and profit margins of airport operation. Therefore, non-aeronautical revenues have been recognized and acknowledged by the airport industry to contribute to greater growth of global airport revenues. According to Galleja^[2] (2017), non-aeronautical revenues play an important role in the revenues and profits of airports in the world, so different airports in the world have tried to increase the non-aeronautical revenue streams to increase the revenue per passenger; the non-aeronautical revenues in the world have contributed 40 percent of the global airport revenues, whose total industry value was up to \$60.6 billion. The greater revenues from non-aeronautical revenues tend to offer airports with “more diversification of income streams” which provides a better cushion in times of economic recessions that tends to reduce the number of

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passengers. Non-aeronautical revenues come in different sources of income including advertising, food and beverage, car parking, pickup and delivery service, and so on. It is important for the airport managers to gain a better understanding of different fields of non-aeronautical services that serve as an important revenue source as well as how to better manage these fields to bring greater profits and incomes for the airport.

2. Different Fields of Non-aeronautical Revenues

2.1 Airport Advertising

Airport can generate non-aeronautical revenue through selling advertising space for businesses inside and outside of the terminals, because there are a lot of spaces inside and outside of the terminals and that there are hundreds of thousands of passengers visiting the airports. According to AirIT¹ (n.d.), airport has been one of the ideal places of advertising for different kinds of products or services, which is especially true when it comes to the fact that the purchasing power of visitors and travelers in the airports is usually much larger than the average person. Advertisements in the airports can take both conventional form and digital form and there is a growing trend of the adoption of digital form by more and more businesses and marketers. One salient advantage of airport advertising is that airport advertisements fit in with different kinds of channels and can be applied in the terminal, gates, and corridors and other places inside and outside of the airports² (CAPA 2015). Because people tend to stay in airport for a long time due to the long waiting and dwelling time before boarding the plane, which increases the probability for visitors to notice and pay attention to these advertisements. A survey shows that a large proportion of visitors to airports would notice airport advertisements and would take the time to reading the message, especially for those frequent fliers who normally “take three or four round-trip flights in a year”³ (Ruane 2013).

Airport advertising is also an important source of revenue for different Australian airports, which plays an important role in facilitating the revenue growth of the airport industry in Australia. According to Davey (2017)⁴, the past decade has seen the revenue growth of more than \$1.57 billion for the major Australian airports if the prices charged for access to airports for the passengers remain constant. Airport advertisement also played a role in contributing to the revenue growth of the airport industry in Australia. Many airports in Australia has long realized the importance and growth potential of airport advertising, many Australian airports try to actively attract businesses

and marketers to do advertisements in varying forms in the airports. In the corporate website of Sydney Airport, Sydney Airport argues that “as the number one retail precinct in Australia, Sydney Airport is an unprecedented traffic hub with the unique ability to create bespoke experiences to increase brand awareness engagement with a vast captive audience”⁵ (Sydney Airport n.d.).

While airport advertising is an important source of revenue for many airports, it remains a problem for the airports to consider how to develop “optimal ways of achieving maximum efficiencies that deliver value to the stakeholders” while creating an excellent airport environment; if the visitors to the airport are bombarded with too many advertisements, it may make people to think that what the airports do are simply wanting to maximize profits instead of creating a more favorable and free airport environment.

2.2 Food and Beverage (Rent Fee)

The rent fee of spaces for the food and beverage businesses is also an important source of revenue for the airports. Airport is one of the transport hubs that enjoys a great number of visitors; and airport is a place where visitors tend to come early and stay for a long time before boarding the planes, which creates huge business opportunity for many businesses, large and small, thinking that the huge flow rate can ensure the constant and great revenues and profits. While using the spaces and locations provided by the airports, the businesses need to be charged with higher costs of lease rentals. It is the higher costs of lease rentals that offer a great number of additional revenues for the airports. According to Gorce (2017)⁶, the rental fees account for 8 percent of the total revenues for these businesses. This is an important reason why the rent fee of food and beverage businesses serves as an important source of income for many airports. This is also an important reason why airports are willing to develop more favorable places and locations for different food and beverage businesses and retailers. For example, Sydney Airport initiated a large-scale renovation program across all terminals at the cost of \$3 billion and “major brands are lining up for a presence and are willing to pay some of the highest rent per square metre in the country”; and the average rent charged for premium location is twice of the average price in Sydney and Melbourne, up to \$16,000 to \$24,000 per square metre a year (Cummins 2015)⁷.

However, the problem for the leasing services in the airport is that the airport needs to consider how to better manage these businesses, make sure that these businesses operate in accordance with the agreements and contracts, and maintain good relationship with the businesses. It is

reported by Gardner (2010) ^[1] that some businesses in the Sydney airport were reported charging 25 per cent more for food and pharmaceutical than at shops merely a few kilometers away, which has violated the agreements and clauses; but these businesses show that they were actually forced to violate these agreements and clauses due to the high operating costs in the airports. If the airport cannot manage this well, it may undermine the relationship of the airport with the businesses and the image and reputation of the airport.

2.3 Car Parking

Car parking service is also a major source of revenue for many airports. Many people choosing to take the aircraft to the airports may choose to park their cars on the parking lots offered by the airports. While many people take for granted that there is no relationship between airport car parking and passenger spend, holds that airport car parking services actually account for 25 percent of commercial revenue. It stresses the important role of car parking service for the increase and growth of revenues for airports. He furthers that airport car parking service also serves as a double-edged sword and there is always a tradeoff between revenues and parking charges; the increase of parking charges may also affect the passenger departure lounge spend. In addition, the parking services offered by airports are recently undermined by the car-hailing services outside the airports. It means that many people would choose to select and use the car-hailing services instead of driving their cars and use the airport services. This would potentially undermine the revenues of airports from car parking services.

3. Suggestions

As has been mentioned, the airports need to consider how to develop optimal ways of achieving maximum efficiencies that deliver value to the stakeholders while creating an excellent airport environment. In order to maximize the advertising revenue potential while not affecting the image and reputation of the airports among consumers, the airports need a more functional control and scheduling to manage the advertising contents for different businesses and marketers. The airports can employ some professional companies to help contribute to a more functional control and scheduling to manage the advertising contents for different businesses and marketers. If not, the poor management and scheduling of airport advertising would damage the images of the airports especially of the large, international airports while reducing the revenues of these airports.

It is also mentioned that airport needs to consider how to better manage these businesses, make sure that these businesses operate in accordance with the agreements and contracts, and maintain good relationship with the businesses. To this end, airports needs to improve and perfect the leasing policy and strategies that promote better organization to leasing, encourage transparency and consistency, and reduce ad-hoc decisions to prevent inadvertent noncompliance ^[1] (Willis 2009).

It is still mentioned above that the airport car parking service may lead to the increase of parking charges may also affect the passenger departure lounge spend; airport car parking service may also be undermined by the growing popularity of car-hailing services outside the airport. It suggest that airports can establish an effective pre-booking system in place that incorporates with the airport website in order to enhance capacity management, parking revenue management, improve market penetration, and so on. In order to tackle the threats from the car-hailing services, airports could cooperate with the ride-hailing services to provide car-hailing services for people in the airports.

4. Conclusion

This report emphasizes the non-aeronautical revenues of airports that are playing an increasingly important part in the revenues of airport, which delves into airport advertising, food and beverage and car parking. It shows that although these fields of non-aeronautical services can potentially bring in a lot of profits and revenues to the airports, different airports also need to adopt proactive policies and strategies to improve these fields to increase their revenues and competitiveness. For example, for airport advertising, airport can employ some professional companies to help contribute to a more functional control and scheduling to manage the advertising contents for different businesses and marketers. For food and beverage, airports need to improve the leasing policy. For the airport car parking service, different airports need to establish an effective pre-booking system and cooperate with the ride-hailing services to provide more benefits and convenience to the passengers.

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