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How are automobile fuel quality standards guaranteed? Evidence from Indonesia, Malaysia and Vietnam

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ABSTRACT

This paper aims to demonstrate the governance of gasoline/diesel supply policies and fuel quality management policies in Asia (Indonesia, Malaysia and Vietnam). We highlight two aspects of fuel quantity and quality management by looking at 1) automobile fuel supply policy and refinery development, and 2) emission regulation and fuel quality monitoring systems (FQM). This research allows us to visualize emission regulation time schedules with refinery updates and fuel quality regulations (Tables 2, 3 and 4). We composed specific data from the real world to create tables on the time schedule from refinery update, vehicle emission introduction to fuel quality. This enables us to understand why fuel quality regulations were delayed in the past and when they will be improved in the future, from a realistic point of view. We also visualized the flow of FQM operation (Figs. 1, 2 and 3) which can be developed from the different market structure of each country. FQM can be summarized as 4 incentives and disincentives: trace causes, sample size, frequency of inspection and strict punishment as a design of FQM operation. Our specific case studies may suggest policy direction and influence scenario analysis on fuel quality improvement.

1. Introduction

1.1. Governance of fuel quantity and quality for air quality improvement from vehicles

The growth of motorcycle/passenger vehicle registration could be a driving factor for growing automobile fuel demand. The Southeast Asian region expects to have 26 million cars and 1.6 million trucks in 2040 (International Energy Agency IEA, 2017b), and the fuel demand in Southeast Asia will increase from 4.7 mb/d in 2016 to 6.6 mb/d in 2040 in the New Policies Scenario (International Energy Agency IEA, 2017a).

The Asia-Pacific region will have the largest demand for gasoline and diesel in the world in 2035 due to a rapid increase of mobility. In the gasoline market, China and India will still be self-sufficient in 2020, but some ASEAN countries (Indonesia, Malaysia, Myanmar, the Philippines and Vietnam) will increase gasoline imports (Japan Petroleum Energy Center JPEC, 2016b; Inamura, 2017; JPEC, 2017).

At the same time, fuel quality specifications (gasoline and diesel) will become stringent due to tighter emission standards by 2025 in the Asian region.

At present, refinery capacity in Asia dominates 36% of global capacity and it is expected to expand up to 47% by 2040 (JPEC, 2017). Fuel quality improvement is not easy because it requires a huge investment for refinery upgrades. The share of secondary facilities of refineries for gasoline and low sulfur diesel in Asia is lower than the world average. Developed countries have achieved a Euro 6 equivalent level at present. China and India will upgrade domestic refineries to introduce a Euro 6 equivalent (China)/Euro 5 equivalent (India) in 2020, while Southeast Asia plans to introduce Euro 4 or Euro 5 by 2025. Significantly, Southeast Asia has relatively limited upgrading and desulfurisation capacity in most existing oil refineries (Institute of Energy Economics, Japan IEEJ, 2013; International Energy Agency IEA, 2017b; JPEC, 2017; Asia Pacific Energy Research Centre APERC, 2018; Fesharaki, 2018).

In this study, we have selected three rapidly developing Asian countries which are facing issues due to the expansion and modernization of motorization. We have selected countries that either import or export fuel, but that are not self-sufficient at the present time, and that reflect similar issues as other developing countries around the world. In addition, these three countries have typical development patterns: Malaysia (high GDP, large share of private cars), Indonesia (middle GDP, shift from motorcycles to private cars) and Vietnam (low GDP, motorcycle dominated). Common points among the three countries are oil imports, refinery development and the introduction of biofuel.

Automobile fuel supply policies need to aim at procurement for the growing automobile fuel demand according to fuel quality specifications. The World Energy Outlook (IEA, 2016) focused on fuel supply and fuel quality policy measures on air pollutant emissions with a simple A-I-R typology.

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Air pollution measures are categorized in 3 groups: **A**void pollutant emissions by improving of fuel use efficiency, **I**nnovate policy and technology by economic incentives and **R**educe impact by stringent emission regulations.

This study discusses the typology of "R": how to reduce pollutant emissions from the automobile sector with given typologies of "A" and "I". Regarding the typology "A", we describe refinery supply in the future and the time schedule of refinery plans of cleaner automobile fuels. In Indonesia, the current energy policy was prepared in 2011 based on expected depletion after 12 years (Jiji, 2011; Japan Petroleum Energy Center JPEC, 2015b). Current domestic crude oil supply will increase up to 1.77 million BPD by 2025 (Takagi, 2016; Japan Oil, Gas, and Metals National Corporation JOGMEC, 2017), which could cover 90% of demand in 2025. Indonesia re-joined as a member OPEC to strengthen their relationship with the Middle East to help crude oil imports and refinery updates. As for Malaysia, one goal of the Refinery Plan seems to have been completed with an oil refining and storage hub in Singapore. The domestic crude oil supply will increase up to 1.04 million BPD by 2025, which could cover 90% of demand in 2025. In Vietnam, crude oil production has been decreasing since 2004. On the other hand, energy demand has doubled in 10 years. The total capacity of all planned refinery development is expected to be 166% of expected demand in 2025 (Japan Petroleum Energy Center JPEC, 2015a; DEA, 2017).

Regarding the typology "I", we provide only actual situations of automobile fuel subsidies. Subsidies for gasoline and diesel are critical components to re-shape both sides between quantity and quality by providing incentives by governmental design. Low fuel prices as a result of subsidies may delay investment in oil refineries in many countries, and subsidized fuel prices should be coordinated as one direction of automobile fuel supply policy and environmental performance. Price distortion by subsidies also leads to over consumption of fuels and smuggling, as well as the aforementioned problem of adulteration. Imported products could be provided through various distribution chains by trade liberalization.

Regarding the typology "R", this paper mainly discusses vehicle emission and fuel quality regulations put in place to avoid fuel adulteration. It is necessary to adjust fuel properties for rendering fuel suitable for the vehicle technology level of particulate matter (PM) reduction equipment that is used after treatment. A certain amount of kerosene in automotive diesel cannot be immediately detected but gasoline with an added 5% of kerosene could lead to knocking (Kojima, 2016). Improvement of vehicle fuel quality, especially sulfur contents, will contribute to the improvement of PM created by the automobile sector. Trends of the Asian fuel market heads toward 10 ppm of sulfur contents by 2025. Research Octane Number (RON) and cetane indirectly contribute to air quality improvement. Higher numbers of RON and cetane are better for the environment. Lower indexes are more reasonable prices. They are often subsidized for low income groups.

The components "A", "I" and "R" are mutually related. However, information on stringent emission regulations "R" are sometimes independently provided by different sources, which results in confusion in markets and impacts vehicle production. This paper observes the evolution of emission regulations by considering the availability of automobile fuel demand "A" and incentives/disincentives on fuel quality monitoring "I". This enables us to understand why fuel quality regulations were delayed in the past and to estimate realistic emission regulation schedules.

1.2. Air quality and emission for mobile sources

Fuel adulteration has detrimental effects on vehicular and air qualities, and consumers then have to cover the costs related to vehicular problems (FI, 2016; FM, 2016).

According to a report of the Climate and Clean Air Coalition (CCAC), United Nations Environment Programme (UNEP) and Asia Pacific Clean Air Partnership (APCAP), 92% of the population of Asia and the Pacific, 4 billion people, are exposed to air pollution with a significant risk compared to the World Health Organization guidelines (WHO, 2006) in 2015 (CCAC/UNEP/APCAP, 2018). Table 1 shows air quality ratings of large cities in the above three countries under WHO guidelines. Air quality is a result from emissions of various sectors. Death from air pollution at a city level can be estimated as 1264 deaths in Jakarta (2014) and 130 deaths in Kuala Lumpur (2013) (Hirota et al., 2017). There is no parameter available to estimate for Vietnam.

Table 1
Air quality (PM10) rating in the 3 countries

City	1990-1995	2002-2005	Latest	Year of latest data
Jakarta	E	E	D	2014
Kuala Lumpur	B	D	D	2013
Hanoi	E	E	E	2014
Ho Chi Minh City	E	E	E	2007

A	50% of WHO guideline
B	Within WHO guideline
C	Within 200% of WHO guideline
D	Winthin 300% of WHO guideline
E	Over 300% WHO guideline

Table 1 demonstrates the air quality rating of PM10 (annual average) in four cities of the three countries with the criteria of WHO guidelines (Asian Development Bank (ADB and the Clean Air Initiative for Asian Cities (CAI-Asia) center, 2006a, 2006b, 2006c); Nguyen, 2008; Clean Air Initiative for Asian Cities (CAI-Asia, 2010a, 2010b); Air Quality Monitoring, n.d.). The guidelines specify the levels of air quality by A–E, where A stands for a 50% level of WHO guidelines, while B, C, D, E exceed WHO guidelines. In the year 1990, Jakarta, Hanoi and Ho Chi Minh City had the rating "E" (over 300% of the WHO guideline) while Kuala Lumpur was rated as B (within WHO guidelines) in 1990–1995. Ratings of PM10 in Jakarta improved, but still exceeded levels as E (over 300% of the WHO guideline) to D (within 300% of the WHO guideline) (DKI Jakarta, 2016). The ratings of Kuala Lumpur worsened from B to D (DSM, 2014). The ratings of Hanoi and Ho Chi Minh City remained the same at E (MONRE, n.d.; Nguyen, 2008; Hung, 2010).

A rapid increase in the number of vehicles may cancel out efforts of air quality improvement. PM emission from mobile sources contributes 36–52.4% in Jakarta (2008–2013) (Guttikunda, 2015; Karagulian et al., 2015), around 65.9% in Kuala Lumpur (2004–2008) (DSM, 2014; Karagulian et al., 2015) and 36–46% in Hanoi (2001–2008) (Guttikunda, 2008; Karagulian et al., 2015). In order to reduce automobile emissions, fuel quality according to vehicle emission regulations are the first requirements.

Once fuel quality is improved, the quality of fuel products should be monitored systematically and regularly and compared to fuel quality standards because there is no information of fuel quality in many developing countries, on the consumer side. Fuel quality monitoring (FQM) is designed by the oil market in each country. It is not a "one-fit-for-all" model. The cases of Indonesia, Malaysia and Vietnam demonstrate lessons on FQM procedures which other developing countries can learn from.

2. Indonesia

2.1. Gasoline/diesel/biodiesel demand

Motorcycles were still dominant at 82% while the share of passenger cars was only 10% in 2014 (50 passenger cars per 1000 people). The average annual growth rate (AAGR) of registered vehicles in 2009–2015 was 7% (JETRO, 2001-2017; BPS, 2000-2015; IRF, 2016; JAMA, 2016). Total consumption of gasoline and diesel was 362 thousand barrels in 2015. Gasoline consumption was 184 thousand barrels, and diesel consumption was 178 thousand barrels. Indonesia imported 58% of gasoline demand and 26% of diesel demand in 2015 (International Energy Agency IEA, 2017c). The government prohibited export of fuels in 2014 in order to prioritize

domestic consumption. The annual growth rate of gasoline demand will be 8% from 2012 to 2025. Gasoline and diesel imports will be increased due to a shortage of refineries for imported crude oil and gas. Instead of the decreased demand of pure diesel from 2014 to 2015, consumption of biodiesel has increased.

RON 88, RON 92 and 95 are available in the market. RON 88 is the most dominant product. RON 95 has very limited share, at only 0.34% in 2015. Before July 2006, Indonesia produced automobile gasoline with different Research Numbers RON: unleaded Premium (RON 88), unleaded Pertamax (The previous name: Premix) (RON 92), and unleaded Pertamax plus (The previous name: Super TT) (RON 95) (OECD, 2013). Only one state-owned company can manage the supply of RON 88.

Indonesian biofuel policies currently focus on biodiesel for domestic consumption and the development of the biofuel industry. Biodiesel policy targeted 20% (20% biodiesel blend: B20) in 2016 and plans to target 30% (30% biodiesel blend: B30) in 2020 (Wright and Rahmanulloh, 2017).

2.2. Gasoline/diesel/biodiesel subsidies

RON 88, having the lowest price among gasoline fuels because of subsides. RON 92 and RON 95 are not subsidized so their prices are higher than that of RON 88. Subsidies of RON 88 were phased out on January 1st, 2015. Subsidies for diesel prices were fixed as Indonesian Rupiah (IDR) 1000 per liter from January 1st, 2015. The IEA analysis estimated 24% and 54% of gasoline and diesel prices were subsidized in 2005 (IEA, 2006).

The phase out of subsidies saved the government around IDR 120 trillion ($9 billion) of revenue in 2015, which is around 30% of total governmental expenditure. The saved revenue has been redirected to infrastructure development and social programs.

Biodiesel was subsidized IDR 1000 per liter in 2009, and IDR 2000 per liter in 2010, which was a slightly lower price than that of Cetane 53 (JETRO, 2001-2017; Wright and Rahmanulloh, 2017). The Indonesia Oil Palm Estate Fund (BPDP) collects a palm oil export levy and redistributes it to biofuel producers for domestic sales of B20 mixture as a biofuels subsidy (Kharina et al., 2016).

One of the reasons for possible fuel adulteration is fuel price hikes. It becomes quite profitable to mix low-cost fuels with higher priced fuels, thus providing incentives for impropriety. The fuel monitoring results for lead content by the Ministry of Environment in Indonesia and an Indonesian environmental NGO called KPBB found that all the samples met fuel requirements in 2003 and 2004. However, they found that 12 out of 31 samples exceeded the lead standard in 2005 (Tamin, 2008; KPBB, n.d.; Sarfudin, 2008).

2.3. Refinery upgrade, vehicle emission and fuel quality standards

There was discussion on the introduction of Euro 4 in 2013 and 2017, but it was postponed according to fuel availability. Table 2 shows that the supply of Euro 4 fuel became available from a refinery in 2017 (Institute of Energy Economics, Japan IEEJ, 2016; JPEC, 2017), however the share of production is only 14% in the Indonesian market (ESDM, 2016; FI, 2016; IOI, 2016; Sarfudin, 2016; MOEF, 2016; Indonesia Investment, 2018; Sarfudin and KPBB, 2018). Gasoline vehicle emission regulations were updated up to Euro 4 by the Ministry of Environment and Forestry (MOEF) in 2018. Considering the refinery stage, Euro 5 fuel quantity and quality will be provided by 2023.

2.4. Retail/sales share and fuel quality monitoring (FQM)

Oil refining, transportation, storage, and the retailing sector are liberalized in 2008, but a state-owned oil company is dominant both at the refinery and gasoline station stages (US EIA, 2015).

The Oil and Gas Agency of the Ministry of Energy and Mineral Resources (MIGAS) rules mandatory sampling checks for automobile fuels. LEMIGAS, which is a government research institute affiliated with MIGAS, conducts mandatory sampling tests from depots to gasoline stations jointly with the state-owned oil company (JCCP, 2013).

The sampling number is 150–200 samples of each fuel per year taken from gasoline stations by LEMIGAS (Hirota, 2010). On the other hand, the state-owned oil company is required to conduct a quality check of all shipments sent to its directly-operated vendors, depots and gasoline stations. It conducts separate voluntary checks on about 100 samples of each fuel per year for in-house management purposes (ESDM, 2016; Sarfudin, 2016; Sarfudin and Komite Penghapusan Bensin Bertimbel (KPBB), 2018; Aw and SA, 2018). Despite these efforts, the following points remain (Fig. 1):

1. The procedure of tracing adulteration points may not be clear.
2. The latest monitoring by LEMIGAS seemed to be in 2011.
3. The quality from the refinery to the gasoline stations is monitored by the company.
4. It is notable that FQM punishment highly depends on in-house regulations of the company. Punishment consists of two stages. In Stage 1, product supply is reduced, and in Stage 2, supply is cut off for 2 weeks.

3. Malaysia

3.1. Gasoline/diesel/biodiesel demand

The share of passenger cars was 49% while that of motorcycles was 45% in 2014 in Malaysia (382 passenger vehicles per 1000 people, 2014). The average annual growth rate (AAGR) of registered vehicles 2005–2014 was 7% (JETRO, 2001-2017; MTM, 2015; IRF, 2016; JAMA, 2016). Total demand of gasoline and diesel was 23 million tons of oil equivalent (TOE) in Malaysia in 2014. Gasoline consumption was 13.4 million tons of oil equivalent (TOE). Diesel consumption was 9.2 million TOE. Malaysia imported 59% of its gasoline and 47% of its diesel in 2015 (Energy

Table 2
Comparison of the schedule at refineries and gasoline and diesel vehicle emissions and their fuel quality regulations in Indonesia (gasoline passenger cars).

Emission/ Fuel standards	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Refinery stage	Euro 2							Euro 4			Euro 5					
Emission standard	Euro 2								Euro 4					Euro 5		
Gasoline fuel standard (Official)	Euro 2							Euro 4						Euro 5		
Gasoline fuel property in Market	Euro 2							Euro 4						Euro 5		

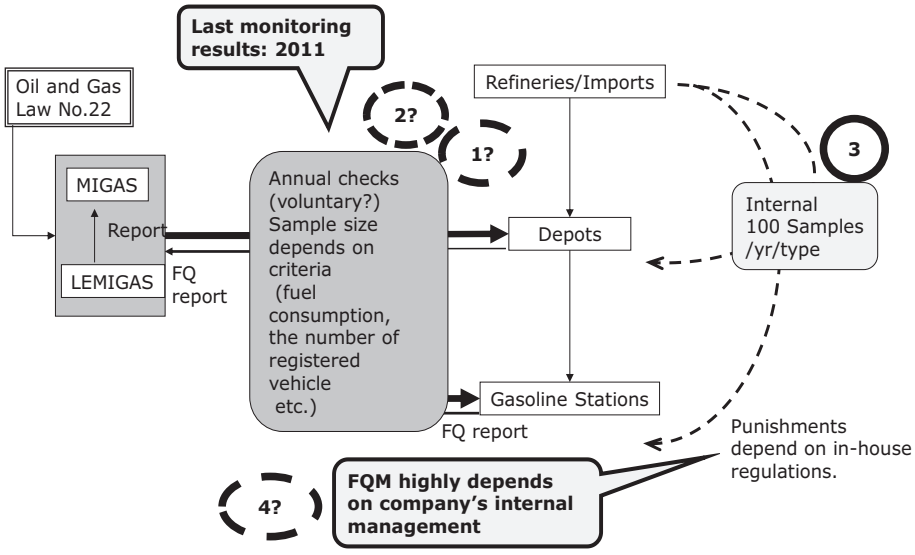

Fig. 1. Fuel quality monitoring in Indonesia.

Commission, 2015; Energy Commission, 2016; International Energy Agency IEA, 2017c).

RON 95, RON 97 and automobile diesel (Euro 2M/Euro 4M/Euro 5) are available at gasoline stations (Jiji, 2014). Regarding biofuels, the government initially implemented B5 (5% of biodiesel blend) gradually by region in 2008: Peninsular Malaysia, the central region (Negeri Sembilan and Selangor) by 2013 and the southern region (Melaka and Johore) on 2012. The northern region (Perak, Penang, Kedah and Perlis) on 2014 and finally the east coast states (Pahang and Kelantan). All regions had implemented B5 and it became mandatory in July 2014. The government implemented B7 (7 % biodiesel blend) in 2015 and plans to implement B20 by 2020 (DOE, 2018; Jiji, 2019; MARii and MITI, 2020).

3.2. Gasoline/diesel/biodiesel subsidies

The government phased out subsidies of RON 97 in 2010. RON 95 seems to be subsidized (Jiji, 2008; DOE, 2018). With respect to subsidies for automobile fuels, IEA analysis estimated 26% and 37% of gasoline and diesel prices were subsidized in 2005 (IEA, 2006). Prices are now set monthly based on movements in international markets (JETRO, 2001-2017; Wahab, 2017). The government phased out subsidies in 2014 and postponed reintroduction of the subsidies in 2020 (Jiji, 2020), according to news sources. Bioethanol is not available while B30 will be applied in 2025 or earlier. (Wahab, 2017; MARii and MITI, 2020). The government revised to implement B15 by 2020 in the 11th malaysian Plan (2016-2020) (Wahab, 2017).

3.3. Refinery upgrade, vehicle emission and fuel quality standards

The Government announced a Euro 4 introduction schedule in 2013, but it was not agreed upon by the oil industry in 2014. Euro 4M gasoline became available for RON 97 in September 2015 (Jye and MAA, 2016) thanks to updates of three refineries. Table 3 shows that Malaysia plans to implement Euro 4 by 2020 because Euro 4M gasoline for RON 95 will be available in 2020 due to a refinery update (Jiji, 2014, 2015; FM, 2016; JKT, 2017; Platts S&P Global, 2018).

Malaysia's Refinery and Petrochemical Integrated Development (RAPID) project, hopes to position the country as a major product exporter in Southeast Asia. RAPID was scheduled for completion in 2019 (Yamaura, 2000; Japan Petroleum Energy Center JPEC, 2014; TBT, 2016). The project is expected to produce high-specification gasoline and other products from around 2020. It is notable that the actual fuel in the market is ahead of the required regulations. Malaysia plans to introduce Euro 5 for RON 95 and RON 97 gasoline in September 2025.

3.4. Retail/sales share and fuel quality monitoring (FQM)

The market share at gasoline stations is different from the market share at the refinery stage. A state own oil company, Company A and Company B are the main refinery companies. Company C and Company D, which do not have a share at the refinery stage, imported better fuel products such as Euro 5 diesel before regulation started (Jiji, 2005, 2007, 2014; METI, 2014) As for FQM, the Department of Environment (DOE) rules mandatory

Table 3
Comparison of schedule at refineries and gasoline and diesel vehicle emissions and their fuel quality in Malaysia (gasoline passenger cars)

Emission/ Fuel standards	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Refinery stage	Euro 2					Euro 4										
Emission standard (Official)	Euro 2										Euro 4					Euro 5
Emission standard Auto industry proposal	Euro 1										Euro 4					
Gasoline fuel standard (Official)	Euro 2M					Euro 4M (RON 97)										Euro 5
Gasoline fuel standard (Official)	Euro 2M										Euro 4M(RON 95)					Euro 5

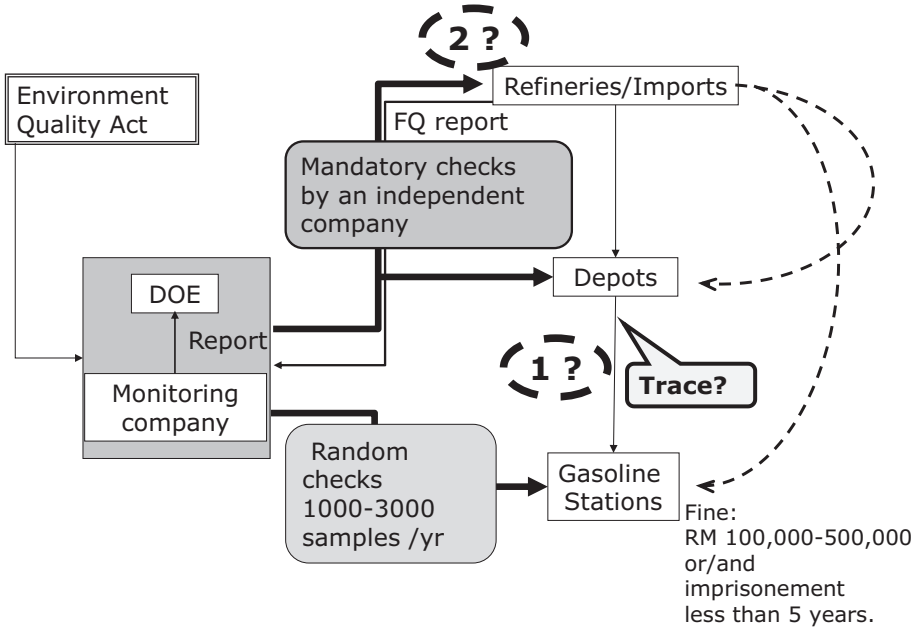

Fig. 2. Fuel quality monitoring in Malaysia.

sampling checks at refineries with submission of a report (GOM, 2007; DOE, 2016; Aw and Stratas Advisors (SA), 2018). Voluntary checks are conducted at gasoline stations by oil companies and the government. The sampling size is large enough at gasoline stations.

It must be noted that Malaysia has a very strong policy on who may distribute fuel because any person who produces, stores, distributes, transports, supplies, sells or offers fuel for sale in contravention of the subregulations needs to pay a fine of 50,000–500,000 ringgit or to face imprisonment for 2–5 years, or both.

The following points of concern remain (Fig. 2):

1. One concern is how to detect the adulteration point because it cannot be traced. Mandatory checks are conducted by a third company at the refinery stage.
2. The number of samplings is unknown at the refinery/import stage.

4. Vietnam

4.1. Gasoline/diesel demand

The share of passenger cars, buses and trucks was only 4% while that of motorcycles was 96% in 2015 (7 passenger vehicles per 1000 people). The average annual growth rate (AAGR) of registered vehicles 2005–2015 was 7% in Vietnam (Hung, 2010; JETRO, 2001-2017; IRF, 2016; JAMA, 2016). The total demand of gasoline and diesel was 1.9 million tons in 2015. Gasoline consumption was 5.6 million tons, and diesel consumption was 9.2 million tons. The rate of imported gasoline was 50% and diesel 62% in 2015 (International Energy Agency IEA, 2017c). The oil import rate was improved from 2009 due to the establishment of the first Vietnamese refinery in Dung Quat in 2009 (Ngoc, 2014; Trung et al., 2016).

RON 92, RON 95 and E5 (5% of ethanol blend) were available in Vietnam by 2017 although selling up to E10 is allowed. (TBT, 2016; Nguyen, 2016a; Nguyen, 2016b). RON 92 was replaced by RON 95 from January 1st of 2018. The E5 share was 30% and RON 95 share 70% in the Vietnamese gasoline market in 2018 (International Energy Agency (IEA, 2017a, 2017b, 2017c); Aw and Stratas Advisors (SA), 2018). Regarding fuel types, regulation allows sales of leaded gasoline, but most products are unleaded in the market. Three types of diesel (5000, 2500, 500 ppm) are available and Euro 5 diesel started to be sold from January 1, 2018 (Jiji, 2017b; VR, 2016).

4.2. Gasoline/diesel/bio ethanol subsidies

Gasoline and diesel prices are still subsidized. According to the IEA analysis, 6% and 26% of final gasoline/diesel prices were subsidized in 2005 (IEA, 2006). The Petroleum Price Stabilization Fund is used to reduce the

Table 4
Comparison of schedule at refineries and gasoline and diesel vehicle emissions and their fuel quality in Vietnam (gasoline/diesel passenger cars).

Emission/ Fuel standards	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Refinery stage	Euro 2									Euro 4	Euro 5					
Emission standard (Official)	Euro 2							Euro 4					Euro 5			
Fuel standard (Official)	Euro 2						Euro 4					Euro 5				
Gasoline/Diesel fuel property in market	Euro 2								Euro 4			Euro 5 ?				

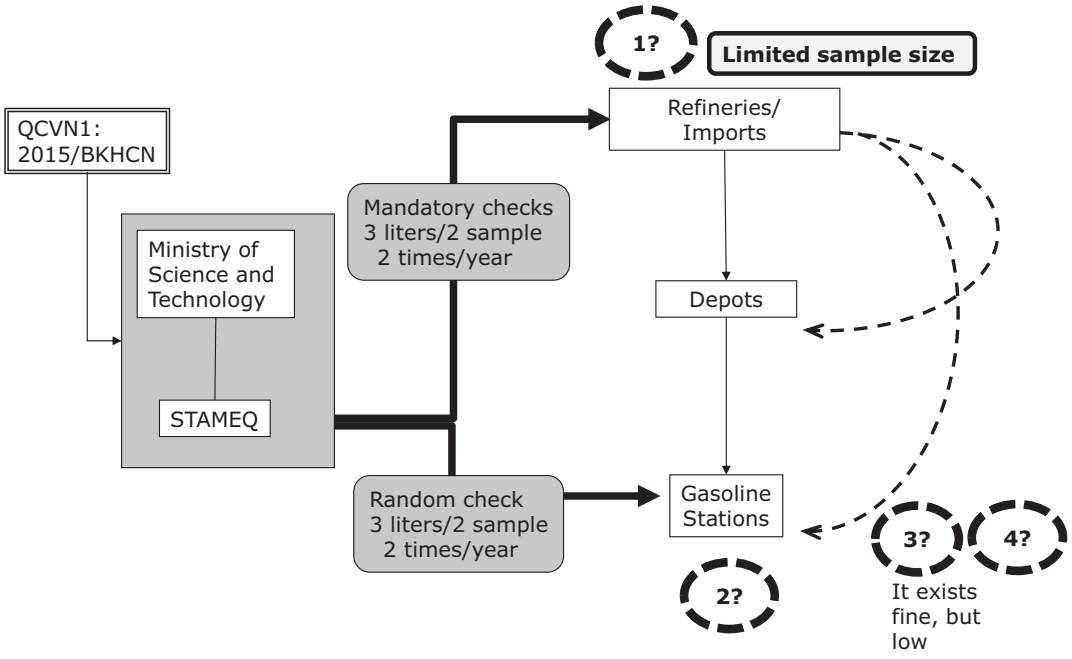

Fig. 3. Fuel quality monitoring in Vietnam.

price fluctuation stemming from changes in international oil prices (JETRO, 2001-2017). The Vietnam government tripled the environmental protection tax in May 2015 when the world oil price dropped.

4.3. Refinery upgrade, vehicle emission and fuel quality standards

Regarding emission regulation, the government introduced Euro 4 in March 2017 (Table 4) (ISPONRE, 2016; PMOGV, 2011; Prime Minister Office Government of Vietnam (PMOGV), 2011), but Euro 4 fuels were not available due to delays of refinery construction. The government postponed Euro 4 application for long distance diesel buses to Jan 2018 and diesel vehicles to 2022 (Jiji, 2017a).

The Vietnamese second refinery was completed in 2018 for the supply of RON 92, RON95 gasoline and EURO4 diesel. Two additional refineries are planned to be completed in 2018–2020 to produce Euro 4 and Euro 5 fuels (JPEC, 2015a). However, an expert suggested that Euro 4 would be implemented in 2019 as an optimistic view and 2022–2025 as a realistic view (Searle and Malins, 2016; Japan Petroleum Energy Center JPEC, 2016a; VAMA, 2016; VPI, 2016; Aw and Stratas Advisors (SA), 2018).

4.4. Retail/sales share and fuel quality monitoring (FQM)

In Vietnam, one state-owned company was established from upstream (R&D) while another was established from downstream (retail development). The share of the first is 100% at the refinery level and 22% of the market at gasoline stations. The second company dominates 48% of the market share at gasoline stations (JCCP, 2013). As with the previous two countries, Vietnamese FQM still faces some issues (STAMEQ, 2016; Aw and Stratas Advisors (SA), 2018) (Fig. 3):

1. The Directorate of Standards, Metrology and Quality (STAMEQ) governs fuel quality. A mandatory check takes 3 l for 2 samples, twice per year at the refinery/import stage. It may be difficult to choose 3 l for 2 samples, twice per year from the whole Vietnamese market.
2. Irregular checks are conducted by STAMEQ when problems occur at gasoline stations. No regular checks at gasoline stations (Jiji, 2012, Jiji, 2016)
3. Voluntary monitoring depends on each company.
4. Penalties exist, but they are very low. They may not be enough incentive to respect fuel quality standards.

5. Discussion of findings

5.1. Summary and discussion

Compared to WHO guidelines, the air quality of the capital cities of Indonesia, Malaysia and Vietnam is over three times the permissible limits. Air quality PM10 ratings show emissions from stationary and mobile sources might cancel out various efforts of policy implementation, but sulfur contents improvement can contribute greatly to the reduction of PM10. The three countries struggle on how to meet the growing demand of automobile fuels and fuel quality according to vehicle emission regulations. As such, this paper focused on different case studies in Asia.

Policy coordination is necessary for the quality and quantity of automobile fuel supply. These governments prioritize automobile fuel supply by domestic production and imports. Future refinery capacity up to 2025 could achieve 91% of expected demand in Indonesia, 90% in Malaysia and 166% in Vietnam, supposing completed refinery development plans. The governments of the three countries expect to increase automobile fuel supply (gasoline and diesel) to meet growing demand by developing oil refineries domestically, by the introduction of biofuels for rural development and by the liberalization of the oil market for domestic economic growth. Better fuel regulations will be disseminated gradually according to the domestic refinery development schedule. Oil importers may introduce Euro 4 and Euro 5 earlier than the introduction of emission regulations.

Procedures of vehicle emission regulation introduction must be coordinated with domestic oil industry development. Each country has different legal procedures caused by different roles of stakeholders (governmental institutes, oil industry, auto industry, NGO, research institutes, consumers, etc.). That caused a different time schedule of regulation introduction among the three countries.

We also focused on operational improvement from the three countries. In the Indonesia state oil industry, one entity dominates from refineries to gasoline stations. The Malaysian market has different segments between the refinery level and retail level. In the Vietnamese oil industry, a state-owned entity dominates at the refinery level, but another national

Table 5
Status of market share and FQM in the three countries.

		Indonesia	Malaysia	Vietnam
Market share	Refinery share of state-owned companies	State-owned oil company 100%	State-owned oil company 63%	First state-owned oil company 100%
	Gasoline stations of state-owned companies	State-owned oil company 98.4%	State-owned oil company 29%	Second State-owned oil company 48% First state-owned oil company 22%
FQM	Monitoring by a neutral institute	Mandatory check by government (LEMIGAS) at depots and gasoline stations	Mandatory check by a neutral institute at refineries Random check by oil industry and government	Mandatory check at refineries by government (STAMEQ) Random check at gasoline stations by government (STAMEQ)
	Monitoring scale	100-150 sample/type/year	Refineries: lot test gasoline stations: 3000 samples/yr	Refineries 3 liter / 2 samples/ 2 times/ year Gasoline stations 3 liter / 2 samples / 2 times/ year
	Transparency	Results are not public after 2007.	Uncertain if the results are public or not.	Uncertain if the results are public or not.

Vietnamese oil import company, dominates 48% of the market share at gasoline stations (Table 5).

Country specific issues exist: company internal management in Indonesia, monitoring costs covered by oil companies in Malaysia, and irregular monitoring at the retail level in Vietnam. An increase of the sampling number, increased frequency of monitoring, an increased budget for human resources and strict penalties will be potential improvement points for the three countries. That is, disclosure, independent monitoring, and scale of monitoring are key issues for FQM improvement.

5.2. Remaining issues

Other remaining issues are inclusive FQM for small enterprises to sell gasoline and diesel for the last one mile, and fuel quality at small scale enterprises in suburban areas. Small gasoline stations which have gasoline pumps in rural areas are not included in the FQM system because of a very small market share, however, motorcycle users often use small stations to buy 1–2 l for the last one mile. Sales of small-scale gasoline stations are unknown, and there may be a huge demand from motorcycle users, which in turn may have a great effect on what national policies are required, yet this area remains unresolved.

Finally, vehicle emission regulation for new cars/motorcycles as well as those for used cars/motorcycles should be strengthened for better quality. This issue should be discussed with inspection systems and registration systems. This paper could not include quantitative analysis due to a lack of available data. This research should be compared with other countries for verification in the future.

6. Conclusion

6.1. Design of FQM operation

6.1.1. Implication for governments

The role of FQM is becoming more and more important due to adulteration risk control (quality certification at gasoline stations). FQM can be summarized as 4 incentives and disincentives based on the complex market. This conclusion suggests implications for both environmental management in these countries, as well as for other developing countries.

1) Trace causes/responsibility: Adulteration can only be detected by FQM safely before traffic accidents and/or air pollution occurs. Monitoring sites should be designed by oil market segment where adulteration may possibly happen when transferring products. If an off-specification situation is detected, a government body can trace the quality by a quality certificate.
2) Sample size: Mandatory checks once a year for all gasoline stations. It would be helpful if costs are covered by the government. One issue could be budgets for inspectors and monitoring facilities/ equipment. Transparency that results from checks could be helpful to raise awareness of fuel quality. Quality certificates should be issued to gasoline stations to provide evidence of the quality of fuel products.
3) Frequency of inspection: For example, the government covers the cost in Japan in order to support the mandatory checks. In European countries, environmental NGOs analyze fuel quality in the market and publish monitoring results to the public.
4) Strict punishment and penalties: Punishment risk drives regular voluntary checks by oil companies. Gasoline stations are responsible for product compliance. Gasoline stations check the quality voluntarily in order to pass the mandatory checks.

6.1.2. Implications for researchers

Fuel quality is an important factor to estimate emission volume/air quality simulation by a mathematical model so an understanding of the real-world situation is vital for academic research, especially when applied to rapidly motorizing societies. If values of fuel sampling are taken into consideration in a simulation model, simulation results would be more realistic. In other words, scenario results by different emission schedules could drive earlier implementation from the point of air quality improvement.

6.2. Policy coordination

6.2.1. Implication for governments

Governments could make policy decisions based on advice from a committee of experts based on technical evidence. It means that a consensus of setting regulations is supported by stakeholders from private companies, industrial associations, and NGOs, and so forth.

Subsidies should link to incentives for consumption of cleaner fuels. Fuel prices are distorted by subsidies for the purpose of consumer protection. When fuel prices increased, fuel adulteration occurred in the case study of Indonesia, especially diesel mixed with kerosene. Governments tend to phase out fuel subsidies due to the improvement of the fiscal balance between revenue and expenditure. Promotion of cleaner fuel support dissemination of environmentally friendly cars is also necessary.

6.2.2. Implications for researchers

Visualization of missing links of coordination could lead to improvement. Usually, various governmental institutes become involved in environmental measures. For example, one institute is in charge of emission regulation and another is in charge of fuel quality standards. A clear map of policy coordination is useful for all stakeholders including international companies and investors.

Comments/advice based on simulation and evidence from independent expert groups could advise the expert committee and the policy decision makers. In particular, the role of experts, which consists of scientists, is critical to provide simulation and evidence. Such objective knowledge based on scientific facts is important for policymakers to set realistic and ambitious targets.

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