ASSESSMENT OF MALAYSIA MANUFACTURING WATER USE BY USING SCORE RATING SYSTEM OF AGGREGATED INDICATORS

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DEDICATION

I dedicate this thesis to my three loving kids Mikael Farish, Nur Izz Zara Sofia and Nur Izz Zya Sarah. Thank you for your love and support even though you may not be able to understand the whole journey. The obstacle faced became a lot more bearable with the three of you by my side. The accomplishment of this thesis symbolizes my passion, success and perseverance in life. May all my children pursue and accomplish your dreams. Winners never quit and quitters never win. Mommy will forever always be here and love you.

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ABSTRACT

Increase in water demand is unavoidable due to the population growth, industrialization, urbanization and change of lifestyle. Aspires to become an industrialized nation, Malaysia has set profound transformation putting the manufacturing sector to spearhead the change and become one of the biggest contributors to the Gross Domestic Product (GDP). Growth of manufacturing sector in Malaysia creates increase of water demand that needs attention for performance evaluation towards sustainability. Many assessment methods have been proposed globally in response to these challenges. Evaluation and optimization of manufacturing water use had been done in economic, environmental, social and technical aspects respectively. Nonetheless, approaches to assess manufacturing water use in an integrated aspect has yet to be conducted. Thus, this research aims to develop a novel composite index to evaluate the performance of manufacturing water demand in a holistic manner. The composite index is called Malaysia Manufacturing Industry Water Benchmarking System (MIWABS) that was developed based on relevant sets of indicators under relevant aspects in sustainability principles and was mapped out with Sustainability Development Goals (SDGs). Selection and establishment of indicators were carried out based on specified filtration criteria through water stakeholder workshop. On the other hand, weightage of aspects was done based on Analytic Hierarchy Process (AHP) method based on water experts' feedback. As a result, a total of nine indicators under four aspects; economic, environmental, social and technical were created. The indicators that were established under MIWABS framework are E1 (percentage of water in production), E2 (cost to treat wastewater), En1 (percentage of recycle water), En2 (wastewater per product), En3 (water per product), S1 (employee water use), S2 (water conservation effort), T1 (percentage of utility water) and T2 (percentage of process water). Based on the AHP feedback through the collective decision made by water experts in Malaysia, it was found that economic indicators had the weight value of 29.6%, while environmental indicators had the weight value of 38.6%. On the other hand, social indicators had the weight value of 16.2% and technical indicators had the weight value of 15.6%. Rubber glove and semiconductor industries were chosen as the case study to validate and demonstrate the MIWABS framework. Selection of these industry subsectors were made based on statistical data from Department of Statistics Malaysia (DOSM) which was indicated as water-intensive industry. From the MIWABS scores, the profiling of these two industries has been presented. The outcomes of MIWABS show potential strategic improvements for Malaysia manufacturing water use. Due to the increase in water demand, encouragement for water recycling shall be introduced. Additionally, the findings also showed that, manufacturing shall opted for alternative water resources such as groundwater and river to minimize water intake competition between other sectors. Improvement of manufacturing water use is important to support this sector so that it can be boosted as an important industry such as rubber glove which had proven to be in stable and vital demand for the world even during economy downfall due to the global pandemic COVID-19. Efficiency of manufacturing sector aligning with National Policy Industry 4.0 shall be taken into account since water is an integral component for the betterment of Malaysia as one of the industrialized countries.

ABSTRAK

Peningkatan pemintaan air bagi memenuhi pertumbuhan populasi, perindustrian dan perubahan cara hidup tidak dapat dielakkan. Sejajar dengan aspirasi menjadikan Malaysia sebagai negara perindustrian, sektor pembuatan kini dilihat menjadi salah satu penyumbang terbesar kepada Keluaran Dalam Negeri Kasar (KDNK) negara. Pertumbuhan sektor pembuatan menyebabkan pertambahan pemintaan air. Melihat kepada senario ini, penilaian ke atas prestasi penggunaan air bagi sektor pembuatan perlu dilaksanakan untuk memastikan kelestarian pengurusan permintaan air di Malaysia. Pelbagai kaedah penilaian prestasi penggunaan air sektor pembuatan telah dilaksanakan bagi menangani isu ini. Ianya telah dijalankan secara berasingan bagi menilai penggunaan air sektor pembuatan terhadap aspek ekonomi, alam sekitar, sosial dan teknikal. Namun, kajian menyeluruh dengan mengintegrasikan semua aspek lestari tersebut masih belum pernah dilakukan. Oleh yang demikian, penyelidikan ini telah memperkenalkan satu sistem penanda aras penggunaan air sektor pembuatan iaitu Malaysia Manufacturing Industry Water Benchmarking System (MIWABS). Sistem ini dibangunkan secara sistematik berdasarkan integrasi indikator-indikator yang penting bagi sektor pembuatan di Malaysia dibawah semua aspek lestari dan diselarikan dengan Matlamat Pembangunan Lestari (SDG). Pemilihan indikator dibuat berdasarkan kaedah saringan khusus melalui sesi bengkel bersama pihak berkepentingan sektor air di Malaysia. Sementara itu, pemberat bagi setiap indikator dibuat melalui kaedah Analytic Hierarchy Process (AHP) yang mengambilkira maklumbalas pakar air di Malaysia. Sebagai hasil kajian, indikator-indikator yang dipilih adalah E1 (% kos air/kos produksi), E2 (kos rawatan air), En1 (% air dikitar semula), En2 (jumlah air sisa bagi setiap satu produk), En3 (jumlah air bagi setiap satu produk), S1(penggunaan air oleh pekerja kilang), S2 (usaha penjimatan air), T1 (% penggunaan air terawat) dan T2 (% air untuk tujuan proses pembuatan). Berdasarkan maklumbalas AHP, keputusan kolektif menunjukkan pemberat indikator ekonomi adalah 29.6% manakala pemberat indikator alam sekitar adalah sebanyak 38.6%. Pemberat bagi indikator sosial dan teknikal pula masing-masing adalah 16.2% dan 15.6%. Industri pembuatan sarung tangan getah dan semikonduktor telah dipilih bagi kajian kes, bertujuan untuk menunjukkan applikasi dan validasi kerangka MIWABS. Pemilihan kedua-dua industri ini adalah berdasarkan statistik pengguna air besar oleh pihak Jabatan Perangkaan Malaysia. Hasil pengiraan skor MIWABS bagi kedua sektor pembuatan ini telah dibentangkan. Hasil kajian MIWABS menunjukkan pengurusan permintaan air di Malaysia boleh ditambahbaik melalui cara meningkatkan kadar peratusan kitar semula air di kilang-kilang di Malaysia. Selain daripada itu, penggunaan sumber air alternatif seperti air bawah tanah dan sungai juga boleh diambilkira oleh sektor pembuatan bagi mengurangkan persaingan pengambilan air terawat dengan sektor lain. Penambahbaikan penggunaan air bagi sektor pembuatan adalah penting bagi menyokong pertumbuhan sektor ini memandangkan permintaan produk seperti sarung tangan getah yang kukuh walaupun dalam tempoh pendemik COVID-19. Kecekapan sektor pembuatan selari dengan pelan Industri Dasar Negara 4.0 Malaysia juga wajar mengambilkira penggunaan air ke arah menjadikan Malaysia sebagai sebuah negara penindustrian.

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LIST OF ABBREVIATIONS

GDP	-	Gross Domestic Product
MSIC	-	Malaysia Standard Industrial Classification
MWIG	-	Malaysia Water Industry Guide
PBAPP	-	Perbadanan Bekalan Air Pulau Pinang
DOE	-	Department of Environment
WSI	-	Water Stress Index
WPI	-	Water Poverty Index
WJWSI	-	West Java Water Sustainability Index
CTM	-	Coal to Methanol
EKC	-	Environmental Kuznets Curve
AHP	-	Analytical Hierarchy Process
MIWABS	-	Malaysia Manufacturing Industry Water Benchmarking System
SDG	-	Sustainability Development Goal
OECD	-	Organisation for Economic Co-operation and Development
CWSI	-	Canadian Water Sustainability Index
GRI	-	Global Report Initiative
SPAN	-	Suruhanjaya Perkhidmatan Air Negara
UTM	-	Universiti Teknologi Malaysia
MEWA	-	Ministry of Environment and Water
DOSM	-	Department of Statistics Malaysia
MCDM	-	Multi Criteria Decision Method
BPMSG	-	Business Performance Management Singapore
DID	-	Department of Drainage and Irrigation
JBA	-	Jabatan Bekalan Air
JPP	-	Jabatan Perkhidmatan Pembentungan
PTT	-	Proximity to Target
CSR	-	Corporate Social Responsibility
UPW	-	Ultra Pure Water
CR	-	Consistency Ratio
CI	-	Consistency Index

MP	-	Malaysia Plan
NWRP	-	National Water Resources Policy
WELPS	-	Water Efficient Product Labelling Scheme
RWA	-	Regulatory Water Accounting
PUB	-	Public Utility Board
JIWW	-	Jurong Industrial Water Works
UPWRP	-	Ulu Pandan Water Reclamation Plant
WDM	-	Water Demand Management
EPU	-	Economic Planning Unit
NWSIRI	-	National Water Services Industry Restructuring Initiative
WSIA	-	Water Services Industry Act
NAWABS	-	National Water Balance System
LUAS	-	Lembaga Urus Air Selangorluas
LSANK	-	Lembaga Sumber Air Negeri Kedah
MITI		Ministry of International Trade and Industry

LIST OF SYMBOLS

Σ	-	Sum
λ_{max}	-	Largest eigenvalue
ω	-	Weight
I	-	Indicator
m^3	-	Cubic meter
RM	-	Ringgit Malaysia
%	-	Percentage

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Moving forward as developed countries, industrialization and urbanization has created pressure to water resources management (Bao & Fang, 2012; Fujii et. al., 2012; Gao et. al., 2008; Jia et. al., 2006; United Nations, 2015). United Nations World Water Development Report 2015 projected manufacturing water demand will increase 400% during 2000 to 2050 (United Nations, 2015) higher than global water demand in agriculture and domestic sectors.

Global Manufacturing Competitive Index shows that, manufacturing strength is clustered in three regional clusters: The North America, Europe and the Asia Pacific. North America and Asia Pacific dominate the top 10 manufacturing competitive nations. Numerous Asia Pacific countries like Malaysia, India, Thailand, Indonesia and Vietnam will emerge as more competitive manufacturing countries (Tohmatsu, 2016). As reported by UNIDO (2018), Asia Pacific is currently the major manufacturing producer in global perspective.

Zooming into Malaysia, the manufacturing sector has seen rapid evolution. From mass production through the use of intensive labour force in production lines, to the use of robotics to increase efficiency, the manufacturing industry is constantly evolving with more infusion of automation. Today, the next phase of evolution is referred to as the Fourth Industrial Revolution or Industry 4.0. (MITI, 2018). As manufacturing sector has proven to be the catalyst of economic development in Malaysia since First Industrial Master Plan (Mohamed et al., 2018), slowing down the pace in not an option. In fact, manufacturing sector is the second largest contributor in national Gross Domestic Product of about 22% (DOSM, 2019).

With respond to the 4.4% growth of manufacturing factories in Malaysia between 2010 and 2015, water demand in this sector has double-fold to support the production demand (DOSM, 2015). World Resources Institute, the developer of Aqueduct Water Risk Atlas, had projected that, Malaysia, despite having 907 billion m^3 of rainfall a year and considered as water abundant country, is facing medium risk of water stress by year 2030 (World Resources Institute, 2020).

Based on statistics from Malaysia Water Industry Guide, record shows increase in demand of water for domestic and non-domestic in Malaysia for the past 12 years. Water consumption in 2002 was 8,487 MLD (Lee, 2005). The demand increased up to 21% to a total of 10,716 MLD in 2014. Besides that, the trend shows non-domestic water consumption is increasing along with the total water consumption (MWIG, 2018). As water demand is being shared among sectors such as domestic, commercial and manufacturing, water stress has been predicted in Malaysia especially in states where manufacturing sectors is concentrated (STAR, 2017).

National Water Commission (SPAN) has outlined nine (9) strategies that aim for better enforcement, optimize water resources and development of research for water industry (SPAN, 2019). These strategies are to curb issues such as water shortage, water pollution and efficient value of water in Malaysia. Among these strategies, water use in manufacturing sector shall play a role as it is expected that, water demand in this sector will continue to increase over the years.

In line with this, it is important to assess the current performance of manufacturing water use in Malaysia. Through empirical performance assessment, significant indicators that affect manufacturing water use can be established. By calculating the performance at factory and industry levels, improvement of these indicators can be identified for future improvement towards water demand management in Malaysia.

1.2 Problem Statement

It is understood that manufacturing water use affects water resources in terms of quantity and quality. In term of quantity, manufacturing requires huge amount of water and interruption is not permissible as it will affect the production. Without proper water demand management, this will lead to water competitiveness and uncertainties in water supply (Aggarwal & Kumar, 2011; Sachidananda et al., 2016). In term of quality, manufacturing wastewater is one of the main causes of natural water pollution and environmental degradation. Without proper policy and legislation implementation, wastewater is often released with only partial treatment or without treatment at all (Ranade & Bhandari, 2014). Even though impact of manufacturing water use is significant, studies on water use in manufacturing received little attention as compared to other sector (Ajiero & Campbell, 2018; Dupont & Renzetti, 2001; Reynaud, 2003).

According to sustainable manufacturing principle, manufacturing continues to improve the value of product while effectively reducing the intensity of materials use, minimizing negative environmental impacts, keep safe for employees, communities and consumers (OECD, 2009). Manufacturing has to correspond with economic, social and environmental aspects while operates in optimum technology (Joung et. al., 2013; Taylor et al., 2014). Thus, performance of water in manufacturing as one shall be assessed in terms of these aspects.

Many methods had been done to assess the performance of manufacturing water use. It includes product benchmarking (Den et. al., 2019), lifecycle assessment (Burnip & Cowell, 2006; Walsh et. al., 2017), water footprint (X. Jia et. al., 2015; Skouteris et al., 2017), strategic planning (Alun Gu, 2017; Shang et. al., 2016), water auditing and econometric study (Kumar & Managi, 2009; Revollo-fernández et. al., 2019; Reynaud, 2003).

From these different approaches, environmental indicators had been used to measure impact of manufacturing water use in terms of water quantity and wastewater generation (Alkaya and Demirer 2015; Envirowise 2007; Saha et al., 2005). Technical and social indicators had also been identified for technology improvement and water conservation awareness (Ajiero & Campbell, 2018; Man et al., 2018). On the other hand, economic indicators measure the value of water in manufacturing sector (Shiwanthi et al., 2018; Walsh et al., 2017).

However, measurement of indicators was carried out in numerous research in the past that focus to improve water use in specific industry such as automotive (Babel et al., 2019; Semmens et al., 2014) and specific factory (Ghisi et al., 2014; Ozturk et al., 2016; Saha et al., 2005). Besides that, effort to aggregate environmental indicators was done based on principles of Industrial Ecology for manufacturing industry in Greece (Gaidajis & Angelakoglou, 2016). Nevertheless, as to date, aggregation of indicators concerning economic, environmental and social aspects has yet to be carried out.

Understanding the circumstances that water use within a factory has many various purposes that creates many relevant indicators, this research is closing the gap by developing a composite index to assess the performance of manufacturing water use in multidimensional aspects based on sustainability principles (economic, social, environment and technical). As mentioned by Joung et al., (2013), aggregating and evaluating indicators in environmental, economic, and social aspects together is a practice to measure the sustainability on a larger scale compared to evaluating it individually. The process of indicator aggregation has resulted a composite index score which provides a more straightforward conclusion on the level of sustainability.

Therefore, this research aims to develop Manufacturing Industry Water Benchmarking System (MIWABS) based on aggregated indicators for manufacturing sector in Malaysia. MIWABS used stakeholder-driven approach where the established indicators and weightage assignment were graded by water stakeholders and manufacturing industry. The said indicators were established through a workshop, while the weightage aspects were classified based on the consensus made by the stakeholders. Through MIWABS, it can be a form of standardization to interpret water situation for manufacturing sector in Malaysia. With such composite index, classification and ranking of each manufacturing factory can be done. Besides that, comparison between manufacturing industry can be identified as well. This would help the stakeholders to identify hotspot and make improvement for Malaysia manufacturing industry water use.

1.3 Research Objectives

The overall research goal is to develop a composite index to holistically access the performance of water use for manufacturing sector in Malaysia towards sustainable water demand management. Following are the objectives to achieve the goals of this research:

1. To develop Malaysia Manufacturing Industry Water Benchmarking System (MIWABS) framework that consists of indicators that are selected based on sustainable principle and SDG.
2. To establish weightage to the indicators by using multi criteria decision method.
3. To designate benchmark and target indicators based on manufacturing sector scenario in Malaysia.
4. To compute the rating score based on actual data collected from selected manufacturing industry in Malaysia to show the application of MIWABS.
5. To utilise the findings of MIWABS as a tool for decision making in Malaysia water demand management.

1.4 Research Scope

The scope for the development of MIWABS are as follows:

1. MIWABS was developed based on composite index approach that consists of aspects and a set of indicators. Establishment of indicators was carried out based on systematic literature review, water stakeholders' workshop, and discussion with SPAN and UTM. The finalized set of indicators are based on specified procedure that considered relevancy, applicability and accessibility to manufacturing sector in Malaysia.

2. Weightage assignment for aspects was carried out by using Analytical Hierarchy Process (AHP). Therefore, a standardized survey questionnaire specifically for AHP weightage assignment was designed and developed. The AHP questionnaires were distributed to water experts in Malaysia. The list of respondents for the questionnaire was discussed with SPAN and UTM. The respondents include government officers, researchers, academicians, officers of water operators and utility manager for manufacturing factories.

3. Normalization of multidimensional indicators was done by using Proximity-to-target (PTT) approach. The indicator's score was calculated based on selected benchmark and target values. Benchmark and targets for each indicator were defined based on specified criteria based on Malaysian policy goals, international goal, guidelines or best data performance. The selection of benchmark and target were based on relevancy and availability of threshold value for manufacturing sector in Malaysia.

4. A questionnaire was developed for data acquisition. The questionnaire was designed specifically to gather information of the established indicators. The questionnaire had been deliberated through the collaboration of SPAN and UTM before it was distributed to selected manufacturing factories.

5. Selection of manufacturing industries were made through scoping process with the Department of Statistics Malaysia based on secondary data from manufacturing census 2015. From the water intensive industry, a list of manufacturing factories was given by SPAN based on the big water user criteria; water consumption over 30,000m^3/month. The questionnaires were distributed based on the final list discussed with SPAN and UTM.

6. MIWABS performance index is determined through aggregation of the indicators score with its respective weightage.

1.5 Research Limitation

The limitation for the development of MIWABS are as follows:

1. Questionnaires feedback from manufacturing factories were on voluntary basis. However, difficulties on gathering feedbacks were faced for data collection.

2. Establishments of benchmark and target values can only be made based on literature threshold values since there is no current policy statement of manufacturing water use.

1.6 Significant of Research

To date, performance assessment of manufacturing water use has not been measured holistically. Through MIWABS, the current performance of water use in manufacturing facility can be quantified. With this, evaluation and improvement can be done in respect to identify relevant indicators.

Besides that, since MIWABS is relevant to water demand management, which is a way forward to water demand management in Malaysia, it can provide reliable information for policy making. Thus, it can help in decision making among the policy makers themselves.

Most importantly, the MIWABS framework is flexible and adaptable with time. MIWABS is not only monitoring the performance of manufacturing water use from time to time, its established indicators can be replaced and reviewed. This is to ensure MIWABS adequately reflects the latest manufacturing water use technology in Malaysia.

In short, MIWABS is a useful tool for the policy makers and facility engineer in the manufacturing sector to continuously measure and monitor the performance of manufacturing water use in Malaysia.

1.7 Thesis Outline

Chapter 1 generates the overview of the research. The background of the research, problem statement, objectives, scope and limitation of the research were thoroughly discussed in this chapter. Lastly, the chapter provides the significant of the research.

Chapter 2 discusses all the relevant literatures that were included in this research. In this chapter, literatures were discussed in several sub chapters which are global water demand, manufacturing water demand, assessment of manufacturing water use, and development of composite index as well as review on existing composite index in water resources management.

Chapter 3 provides an insight towards the research methodology of this research. The research background was discussed, along with the methodological flow chart. Besides that, the establishment of the indicators and framework structure, together with the adoption of Proximity-to-Target (PTT) method were discussed. Weightage assignment through Analytical Hierarchy Process (AHP) and data collection for each indicator were explained as well. Lastly, the aggregation of indicators to form MIWABS were also described.

Results and discussions are explained in Chapter 4 and Chapter 5. In Chapter 4, the results and outcomes of the research were conferred. Under the fourth chapter, the development of the research framework together with descriptions of each established indicator was illustrated. The results obtained from AHP were showed and discussed as well. The type, target and low benchmark on each established indicator as well as PTT scores were also discussed at the end of chapter.

Chapter 5 further explained on MIWABS score calculation. The differences between the selected manufacturing industries were discussed. Besides that, pie radar chart showing indicators profiling were explained. This is to identify the hotspots for improvement in Malaysia manufacturing water use. Then, strategic enhancements based on MIWABS result were proposed.

Lastly, with the results obtained from the research, conclusions, recommendations for future researcher, and limitations of the study were mentioned and discussed specifically in Chapter 6.

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