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Assessing Malaysia's Internet of Things (IoT) Readiness Based On CREATE-IoT Key Performance Indicators

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ABSTRACT

The current nationwide deployment of Internet of Things (IoT) in Malaysia has never been assessed nor benchmarked against any Key Performance Indicators (KPIs). A proven IoT assessment standard called CREATE-IoT has successfully driven IoT projects in European countries, and it is hence used as a benchmarking tool in this research. The assessment that includes both technical and business perspectives concludes that 42 out of 50 KPIs (84%) in Malaysia are in the advanced state. Malaysia is thus rated as an IoT-ready country. However, rooms for improvement exist in the scopes of providing expected duration for completing an IoT service transaction to predict the level of customer satisfaction when using the service – and the ability to produce IoT sensors and devices locally to have sustainable, scalable, and economical continuous IoT deployments.

1. Introduction

Malaysia as a technologically agile nation has planned to deploy nationwide Internet of Things (IoT) infrastructure and services. This plan has been put in a roadmap, however – it has never been assessed. Therefore, the research presented by this paper is meant to assess the current IoT deployments in Malaysia.

The importance of assessing the readiness of IoT platform or infrastructure has been proven to be imperious leading to the success of IoT deployments in the IoT pilot projects in various European cities [1]. These assessments were done using KPIs guided by a standard/manual called CREATE-IoT [1]. It should be mentioned here that this standard has been further enhanced by the authors of this paper in their previous publication available in Nurika and Jung [2]. The assessment covers both technical and business facets of the IoT platform. The assessment outcomes presented in this paper are expected to estimate the current nationwide IoT maturity level in Malaysia.

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The outcome of this assessment would reward the currently deployed IoT services and also would motivate the currently in-plan IoT services to proceed to deployment stage. It may also encourage investors to have faith in IoT industry in Malaysia, which in turn may cultivate the national economy - considering the wide potential use cases of IoT services.

At the more granular level, IoT platform assessments have been done at provider-level [3,4]. However, national-level assessment is still scarce, and this paper would contribute to it in the context of Malaysia.

Malaysia as a technologically agile nation has deployed her nationwide Internet of Things (IoT) infrastructure and services in recent years. The IoT deployment plan has been put in a national key development roadmap, however the deployment of IoT has never been effectively assessed. This research is therefore aimed to present a formal assessment approach to assess the current IoT deployments in Malaysia in the context of her readiness in nationwide deployment.

The IoT platform assessment may have been conducted at the platform providers' context to some extent at granular level, however the assessment at the national level is still scarce [3,4]. This research is thus aimed to contribute to the nationwide IoT assessment in the Malaysian context.

2. IoT Readiness Measurement in Malaysia by CREATE-IoT Standard

The IoT readiness was measured against the KPI constituents provided by the enhanced CREATE-IoT standard [2]. The key documents forming the basis of the measurement are the technical reports published by Malaysian Communications and Multimedia Commission and the Malaysia IoT roadmap by Ministry of Science, Technology, and Innovation [5,6]. These reports would also be compared against the solutions done on similar use cases owned by other enterprises or companies. Table 1 presents the status of the outcomes of every measured KPI.

Table 1
The KPIs' Status Outcomes of Malaysia's IoT Readiness

1.	Dimension:	Technology Development
		KPI
1.	*IoT Devices and Modules: Options for Addition of IoT Devices*	Current plan: The method in use for device additions is "bWave" – an IoT Hub that supports varieties of protocols and standards [5]. Assessment conclusion: Advanced. Plausible benchmark: PTC Kepware [7].
2.	*IoT Devices and Modules: Availability and Readiness of Device Facing APIs*	Current plan: A section in the roadmap of IoT Malaysia mentions that it will become point of harmonisation of myriads of standards [6]. It would establish collaboration between technology providers, academia, and research institutions to build and use common set of APIs and data formats. Assessment conclusion: Advanced. Plausible benchmark: Software AG Cumulocity IoT [8].
3.	*IoT Devices and Modules: Supported Varieties of Device Types*	Current plan: - Healthcare: RAPITA - RFID-based devices to locate hospital assets in real time, Breath Sensor – sensors to measure breathing pattern to detect respiratory illness. - Transportation: LocAware – Devices to track school bus and students utilizing IOT gateway, Global Positioning System (GPS), cellular communication, and mobile app to notify parents when their children have reached schools by tracing the timestamps of children entering/leaving the bus and entering schools. - Retail & Payment: Bluetooth Low Energy (BLE) Proximity Marketing – Bluetooth-based devices that send personalized marketing campaign to people's smart devices.

		- Agriculture: Greenify – Water level sensors, lighting sensors, pH level sensors, temperature sensors, electroconductivity sensors for urban farming use case. - Tyre Management System: Tyre pressure sensors and tread depth sensors to measure and notify about tyre's quality. - Air Conditioning System: Electrical power sensors, refrigerant pressure sensors, and filter pressure sensors to determine when maintenance is needed. - Security and Integrated Flood Network (SAIFON): Closed-circuit televisions (CCTVs) sensors to monitor water level at rivers. - Smart Home: Door sensors, light sensors, motion sensors, fire sensors, temperature sensors. - bWave Hospitality Solution (BHS): Energy sensors and all the sensors of Smart Home. Assessment conclusion: Advanced. Plausible benchmarks: PTC [7] and Software AG Cumulocity IoT [8].
4.	*IoT Devices and Modules: Long Term Cost Efficiency of IoT Platform's Compatible Devices*	Current plan: Almost all devices/sensors are imported from United States (US), European countries, China, and Taiwan [5]. Assessment conclusion: Unsustainable. Imported devices could be too costly since there could be import tax and there is a chance of them being embedded with malware or backdoor programs.
5.	*IoT Devices and Modules: Device Security*	Current plan: There is a plan to consistently update device firmware. However, there is concern regarding imported devices from China that beacon connection with covert servers in China to export data [5]. This makes manufacturing devices locally be an important and urgent matters. These vulnerabilities would be mitigated by the proposed device security practices as follows: - Regular firmware update - Encourage device manufacturers to quickly patch zero-day vulnerabilities - Ensure default device login credentials are changed - Enforce device manufacturers to declare the kinds of data being sent to any servers (if there is any) - bWave IoT platform encrypts all communications and firewall rules are implemented as well Assessment conclusion: Advanced. However, the roadmap does not mention about encryption for data at rest. This should be verified.
6.	*IoT Platform: Platform Security at the Device Border*	Current plan: Plans to implement device registration with security ratings [5]. Assessment conclusion: Advanced. However, additional measures could be added e.g., device whitelisting, device anti-spoofing mechanism, device mapping to users for audit purpose.
7.	*IoT System Monitoring: IoT Platform Monitoring Capability*	Current plan: bWave IoT platform has monitoring feature [5]. Assessment conclusion: Advanced. Plausible benchmark: Microsoft Azure IoT [9].
8.	*IoT Architecture: Size of Data Storage*	Current plan: There is a recommendation for dedicated storage facility to store data long term [5]. Assessment conclusion: Advanced.
9.	*IoT System Functional Design: Service Redundancy or High Availability (HA)*	Current plan: There is a plan for improved availability [6]. Assessment conclusion: Basic. The HA plan is incomprehensive; thus, it should be equipped with geographical redundancy, device roaming, and service failure isolation. Plausible benchmark: Software AG Cumulocity IoT [8] and Microsoft Azure IoT [9].
10.	*IoT Verification, Validation, Testing and Certification: IoT Platform Audit*	Current plan: The Malaysian Communications and Multimedia Commission (MCMC) IoT Task Force was formed to supervise IoT deployment in Malaysia. They have also reviewed IoT papers by International Telecommunication

		Union (ITU), Internet Society (ISOC), Body of European Regulators for Electric Communications (BEREC), and The Office of Communications (OfCom) [5]. Assessment conclusion: Advanced.
2.	Dimension:	Technology Deployment and Infrastructure
		KPI:
11.	*Usages of Open Technology Devices and Platforms: Devices utilizing Public Protocols and IOT Platform based on Open Source*	Current plan: The IoT platform uses bWave that may link up devices from different technologies, vendors, and origins [5]. Assessment conclusion: Advanced.
12.	*Use of Supported Standards: Diversity of Supported IoT Standards*	Current plan: The IoT deployment is set to comply to recognized standards, such as ISO/IEC, Personal Data Protection Department (PDPD), ITU, ISOC, BEREC, OfCom, etc. Assessment conclusion: Advanced. Plausible benchmarks: Software AG Cumulocity IoT [8] and GE Predix Platform's [10].
13.	*Capacity to Solve Interoperability and Connectivity Issues: Convergence of Diverse Protocols*	Current plan: The platform of choice bWave IoT Hub may converge devices with different protocols and standards [5]. Assessment conclusion: Advanced. Plausible benchmarks: Software AG Cumulocity IoT [8] and Microsoft Azure IoT [9].
14.	*Scalability: Reporting Capability and Expandability*	Current plan: In smart aquaculture farm use case, real-time report can be easily created by analyzing data generated by sensors stored in efficient and secured storage [6]. Assessment conclusion: Basic. The roadmap lacks information about report retention duration and whether other use cases are equipped with reporting capability as well.
15.	*Scalability: Tenants' Share of Events*	Current plan: There is plan to enable sharing of data/information across different government agencies. This will build agility and community services can be easily tracked. Assessment conclusion: Advanced.
16.	*Efficiency in The Maintenance, Deployment and Life-cycle of Services and Software Running: Affordability of Service Performance*	Current plan: The current roadmap does not mention about the time duration needed to complete a service transaction. Assessment conclusion: Non-existent. Plausible benchmark: A roadmap should include the time it takes to complete an IoT service transaction.
17.	*Efficiency in The Maintenance, Deployment and Life-cycle of Services and Software Running: Affordability of Data Storage*	Current plan: The roadmap talks about the proposed use of cloud storage for cost-effective storage. Storage compression is also discussed that may reduce storage need by half [5]. Assessment conclusion: Advanced.
18.	*Integration with the existing and new infrastructure*	Current plan: Telecommunication companies (telcos) are involved to deliver IoT applications/services [5]. Assessment conclusion: Advanced.
3.	Dimension:	Ecosystem Strategy and Engagement
		KPI:
19.	*Ecosystem Awareness*	Current plan: The MCMC IoT Task Force has been created to keep abreast with IoT ecosystem. This task force is comprised of nine (9) divisions that cover technical and regulatory IoT compliances including about licensing [5]. Assessment conclusion: Advanced.
20.	*Stakeholders' Engagement*	Current plan: The MCMC makes the IoT roadmap as a reference for stakeholders before their application/service deployments. The stakeholders are also involved in discussion about radio spectrum usage, and they are also required to comply to the Numbering and Electronic Addressing Plan (NEAP). Additional engagement programs have also been planned that relate to international standardization organizations e.g., ISO/IEC and ITU. Relevant

		trainings like CTPR Professional Master Class on Smart Digital Nation, Cities and Communities for stakeholders have also been proposed. Also, stakeholders are being put as consultants to give feedbacks [5]. Assessment conclusion: Advanced.
21.	*External Partnerships and Collaboration*	Current plan: Universities and industrial players have been involved e.g., Microsoft, Alcatel-Lucent, APU, BlueArchipelago, Celcom, Cisco, CREST, CyberSecurity Malaysia, MCMC, EPU, Maxis, IBM, Intel, MDEC, Sapura, SIRIM, Texas Instruments, MIMOS, MOSTI, UTAR, UPM, UTM, IEEE, and many others [6]. Assessment conclusion: Advanced.
22.	*Public and Government Engagement*	Current plan: The national IoT deployment roadmap is governed by government agency called Malaysian Communications and Multimedia Commission (MCMC) [5]. Other public agencies and public Universities have also been participating in the roadmap execution i.e., MIMOS, MOSTI, MDEC, SIRIM, CyberSecurity Malaysia, UPM, UiTM, UTM, Telekom Malaysia, PIKOM, etc [6]. Assessment conclusion: Advanced
4.	Dimension:	Ecosystem Openness and External Collaboration
		KPI:
23.	*Value Chain Openness*	Current plan: The roadmap considers people who work in chipset, device, middleware, system integration, and applications industries. The proposed bWave IoT platform is also being promoted to invite start-ups and SMEs to on-board their IoT solutions. In general, all IoT stakeholders are invited to join the bWave IoT platform and use the roadmap as a point of reference for technical standards and regulatory matters. Assessment conclusion: Advanced
24.	*Inclusiveness and Participation for Third Parties: Value-Adding Data from External Sources or 3rd Parties*	Current plan: SAIFON mobile app has been developed to receive alert from flood monitoring sensors, so that users would be aware of dangerous circumstances [5]. Assessment conclusion: Basic. The current external data integration could have more use cases, for example, weather forecast data can be queried to trigger watering sensor in a smart farm. Plausible benchmark: IBM IoT [11].
25.	*Openness of Business Models*	Current plan: The open and collaborative business model is established by the sharing of the bWave IoT platform license suite that is available for start-ups, companies, academia, and device manufacturers [5]. Assessment conclusion: Advanced
26.	*Open Source Strategy*	Current plan: Inspired by the success of Open Source Initiative in Europe, the Technical Working Group (TWG) proposes that the IoT Open Innovation Framework to be a member-based initiative with participating organizations driving the program with local & global IoT players [6]. Assessment conclusion: Advanced
5.	Dimension:	Marketplace and Business Impacts
		KPI:
27.	*Business Models*	Current plan: Open, collaborative, and mutually beneficial among government, technologies providers, start-ups, service providers, academia, and research institutions [5]. Assessment conclusion: Advanced
28.	*Market Readiness and Monetization Mechanisms: Sale Package*	Current plan: Inter-operator rates are negotiated and can be in subscription form or pay-per-use with possibility of bulk discount. Bundling of equipment, solutions, and provisions may also be included [5]. Roaming service is given via technical coordination & commercial negotiations between roaming partners of the participating countries. Available services include voice, Short Messaging Service (SMS), and data. Assessment conclusion: Advanced.

29. Business Benefits	Current plan: An incubation centre is provided for startups and enterprises to stir commercial ideas [6]. Assessment conclusion: Advanced.
30. Market Competitiveness	Current plan: Following initiatives are made to boost market competitiveness [5]: - Do research in new market value creation based on new technologies & business methods. - Allocate industrial grants - Monitor local content utilisation Assessment conclusion: Advanced.
31. Legal Issues	Current plan: Data privacy protection is applied by executing plans of compliance towards Malaysia's own Personal Data Protection Department (PDPD) and other Internationally accepted regulations [5]. Assessment conclusion: Advanced.
32. Privacy, Security, Trust and Ethical Issues: Data Expiry	Current plan: The roadmap implies the importance of infinite data retention and efficient data compression e.g., using Axis' Zipstream method. Assessment conclusion: Advanced. Plausible benchmark: GE Predix [10].
33. Privacy, Security, Trust and Ethical Issues: Tenants' Regulated Data Sharing	Current plan: Sensors that communicate using LoRaWAN protocol would have the data encrypted with device-specific keys from the device to the application and vice versa. In multi-tenant set-up, the network operator is unable to access decrypted/plain application data or application/session keys. So, they are incapable to sell data to a 3rd party [5]. Assessment conclusion: Advanced.
34. Privacy, Security, Trust and Ethical Issues: Technically and Legally Compliant IoT Platform	Current plan: A framework to harmonize multiple IoT standards called IoT Open Innovation Framework has been created, which will used by the Malaysian Technical Standard Forum (MTSFB) and collaborators from international standardization bodies e.g., IoT-A, IEEE, IET, etc [6]. Assessment conclusion: Advanced. Plausible benchmark: IBM IoT [11], Sri Lankan and Malaysian governments [6].
35. Experience Readiness Level: Rule Activity Management (Programmable Rule)	Current plan: Varieties of complex scenario have been able to be deployed i.e., Smart Waste Sensing, Intelligent Aquaponics System, Temp and Humidity Monitoring Using FAVORIOT for Green Building Applications, Tyre Management System, Security and Integrated Flood Operation Network (SAIFON), IoT Enabled Connected Life Services, etc [5]. Assessment conclusion: Advanced. Plausible benchmark: SAP Leonardo IoT [12].
36. Experience Readiness Level: Self Navigation for Reporting and Data Analytics	Current plan: Mobile dashboard is available for a flood monitoring system called SAIFON [5]. Assessment conclusion: Advanced. Other use cases may also be integrated with a user-friendly dashboard. Plausible benchmark: Microsoft Azure IoT [9].
37. Experience Readiness Level: Comprehensive Reporting and Data Analytics	Current plan: Data analytics has been integrated into different use cases e.g., Smart Hospitality and Video Surveillance. Assessment conclusion: Advanced. The report should be able to be generated under 3 seconds as recommended by Google [12]. Plausible benchmark: IBM IoT [11] and C3IoT [13].
38. Holistic Innovation	Current plan: Holistic comprehensive features are encouraged for Smart Home/Hospitality use case to enhance customer's experience from check-in till check-out. And in general, Malaysia's MCMC has officiated a Master Class program that offers a holistic view of the convergence of IoT via its academy program. Assessment conclusion: Advanced.
6. Dimension:	Societal and Economic Impacts
	KPI:
39. Indirect Revenue Generation	Current plan: The roadmap does not discuss about indirect revenue; however, it can be analyzed that indirect revenue may come from import tax of

	imported devices, device certification fee by SIRIM (Malaysia's body of industrial quality certification), device on-boarding cost to telco network infrastructure, device installation cost, and device maintenance cost. Assessment conclusion: Basic. Indirect revenue sources are implied and need to be explicitly mentioned in the roadmap.
40. Employment Macro-Impact	Current plan: The roadmap infers that Malaysia is confident IoT deployment would create more jobs. This is shown in the number of certified IoT professionals being targeted by the government. The jobs are like to revolve around application/service developers, IoT platform engineers, device installers, device engineers, and IoT researchers. Assessment conclusion: Advanced.
41. User Worktime/Life Impact	Current plan: The included use cases would significantly improve people's well-being, especially the flood monitoring system that will accelerate alert and evacuation. The tyre management system will reduce the time people off from their works since higher severity damage could be prevented. The smart farm will reduce the time people need to patrol their farms. The smart home will reduce the time people need to manage their houses. Assessment conclusion: Advanced.
42. Targeted Social Groups	Current plan: There are diverse groups of people being involved and benefit from the IoT deployment. From the service makers circle, it includes Universities, developers, telcos, and IoT platform providers. While the target users vary from the people who live around flood-prone area, medical patients, car drivers, property developers, farmers, and hospitality staff [5]. Assessment conclusion: Advanced.
7. Dimension:	Policy and Governance Impacts
	KPI:
43. IoT Ecosystem Promotion and Competitiveness Safeguard	Current plan: Both bWave and FAVORIOT IoT platforms are being promoted and there is notion that other platforms may be given freedom of promotion as well, especially for telco-based platforms [5]. Assessment conclusion: Advanced.
44. IoT Standards Promotion	Current plan: IoT deployment is still in early stage in Malaysia, hence, the guidelines and standards are still not extensive. IoT service companies implement what is right according to them. This in turn results in difficulty in obtaining certification from SIRIM (Malaysia's body of industrial quality certification) [5]. Assessment conclusion: Basic. Enforcement of standards should be established clearly for companies to follow.
45. Trusted, Safe, Secure IoT Environment Promotion: Multi-Tenant IoT Platform	Current plan: The bWave IoT platform is able to converge diverse devices from different protocols and standards. However, the technical details about data segmentation/ownership are not mentioned. Another IoT platform in use is FAVORIOT that has currently on-boarded different use cases from different tenants mostly from universities i.e., UTHM (Smart Green Building), Taylor's University (Tyre Management, Breath Sensor, & Smart Aircon) [5]. Similar as the former IoT platform, the shared use of FAVORIOT also does not mention about the data ownership or hierarchy of multi-tenant management. Assessment conclusion: Basic. The multi-tenant model needs to specify the details about data ownership and any hierarchical management.
46. Impact on SMEs, Start-ups and Young Entrepreneurs	Current plan: IoT start-ups would be given license to on-board the bWave IoT platform. The dynamics and varieties of use cases of IoT would allow SMEs, start-ups, companies, and universities to build innovative IoT applications and services [5]. Assessment conclusion: Advanced.
8. Dimension:	Community Support and Stakeholders' Inclusion
	KPI:
47. Developers' Community Accessibility	Current plan: The app and device developers could leverage on the bWave IoT platform using a license suite to on-board IoT solutions [5].

	Assessment conclusion: Advanced.
48. Education Availability	Current plan: The current roadmap includes plan for doing educational campaigns for public to create awareness about both the benefits and issues of IoT. Feedback platform will also be deployed to receive complaints and suggestions from users. Consultation with the industry players will also be done to cope up with the latest IoT trends [5]. Assessment conclusion: Advanced.
49. Accessibility Levels	Current plan: Telecommunication companies in Malaysia have started rolling out IoT services through mobile data subscriptions e.g., Maxis and Modus deliver MDrive (vehicle tracking service), Digi delivers iFleet (business-to-business fleet tracking service), and U Mobile and Axiata deliver Atilze (integrated car solution service) [5]. Assessment conclusion: Advanced.
50. Community Engagement	Current plan: Malaysia's MCMC organization mentions that the national IOT deployment roadmap will be a reference for start-up companies, universities, and Makers community, so that they are aware of the regulatory requirements [5]. Assessment conclusion: Advanced.

The scorecard summary based on the findings in Table 1 is presented in Table 2 below.

Table 2
Summary of KPIs' Maturity Levels

Item	KPI Maturity Level	Number of Related KPIs
1.	Non-existent	1
2.	Basic	6
3.	Unsustainable	1
4.	Advanced	42

There are two (2) concerning KPIs, which are each in non-existent and unsustainable states; Affordability of service performance related to needed duration to accomplish an IoT service transaction is still unknown, which may render the fluency of IoT service become unpredictable. This may affect negatively the user experience. Fluent user experience is imperious to keep customers satisfied and subscribed to the IoT service.

Also, the long term cost efficiency is potentially unsustainable due to the majority of IoT sensors or devices that are still imported. Adding up the freight cost and taxation fee, IoT infrastructure cost could balloon above the allocated national budget. Hence, locally produced sensors and devices are crucial to sustain IoT services scalability in the long term. Ability to produce IoT sensors and devices locally may also be commercialized overseas, especially in European countries where the production cost is higher, but the annual growth of IoT market keeps doubling [14,15]. This trend is expected to continue until at least 2025 [16]. In even wider global scale, the worldwide industry is willing to utilize IoT as a response to the recent Covid-19 pandemic, specifically in the areas of farming, electricity, mining, oil and gas, retail, and logistics, while manufacturing area is forecasted to become the top user by 2030 [17-20]. Other IoT-progressive regions could also be targeted such as Asia-Pacific and North America, while China is predicted to catch up by 2030 [21,22].

Besides industrial sector, consumer sector is also a thriving market that Malaysia could aim, where it comprises over 60% of the whole IoT devices [23]. Furthermore, the local education sector may also be engaged by conducting IoT hackathons. This idea is supported by the fact that IoT and robotic programming have both been a trend in Malaysia [24,25].

3. Conclusions

The findings tabulated in Table 1 implies that IoT platforms and infrastructure in Malaysia are mostly in the ready state for continuous deployment of major IoT services. This sustainable deployment is further supported by the fact that most of her geographical areas are reachable by appropriate telecommunication coverages. Majority of the KPIs are in advanced state standing at 42 out of 50 KPIs (84%). Six (6) are in basic state, while only one (1) is non-existent and another one (1) KPI is in unsustainable state. As such, the overall continuation of nationwide IoT deployment in Malaysia has a high potential to be successful, which subsequentially may automate and accelerate people's daily routines, and improve their work-life balance. Having both mature IoT services and quality well-being would polish Malaysia's reputation in the face of the world and induce more confidence into foreign investors.

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