SEMARAK ILMU PUBLISHING

Journal of Advanced Research in Applied Sciences and Engineering Technology

Journal homepage: https://semarakilmu.com.my/journals/index.php/applied_sciences_eng_tech/index

ISSN: 2462-1943

Automotive Technology and Patent Assignee in Malaysia: An Exploratory Patent

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ARTICLE INFO

Article history:
Received 6 June 2023
Received in revised form 21 August 2023
Accepted 24 August 2023
Available online 28 September 2023

Keywords:
Patent analysis; Automotive technology; University-industry research; Emerging automotive technology

ABSTRACT

The automotive industry in Malaysia has been established for over four decades, following the introduction of the Industrial Master Plan Malaysia (IMP) in 1985, and the subsequent launching of the National Automotive Policy (NAP) aimed at driving the growth of the automotive industry in Malaysia. A key focus of the NAP was industrial research and development to promote the leadership of Malaysian automotive companies in the region. Consequently, the alignment of university-industry research with the NAP is critical in fostering innovation and advancement in automotive technology. This study employs patent analysis to investigate the university-industry research and development of automotive technology in Malaysia. The objective is to identify patent trends in automotive technology developed by university-industry, which can provide crucial insight for researchers and inventors to incorporate the latest patented technology and support future inventions.

1. Introduction

The growth and development of businesses and countries are largely driven by promising technological advancements. These advancements have a significant impact on a company's investments, production, and the national industry as a whole. Moreover, emerging technologies are rapidly and unexpectedly evolving. Therefore, organizations and countries that quickly focus on promising technologies to lead their industry can enhance their competitiveness to a degree that directly affects their survival [26].

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https://doi.org/10.37934/araset.32.2.417432

The automotive industry is one of the major contributors to Malaysia's economy ever since the joint national automobile program with Japanese automobile makers from 1983 to 2003 including the launching of the national car in 1983 [61]. According to Veloso [57] and Veloso and Kumar [58], after the devastating economic crisis of 1997/1998, the ASEAN automotive sector was bouncing back. The top positions of the ASEAN market in 2000 were occupied by Malaysian automakers, followed by Toyota, Isuzu and Mitsubishi. However, in 2008–2009 economic crisis, the global vehicle production declined 3.7% in 2008 and 15.8% in 2009 [40]. At the same time, Asia's vehicle production kept growing by 1.9% and 1.5% during 2008 and 2009. Since the 1990s, the high production growth in less developed nations has contributed to a general shift in output in favor of non-core areas of global automotive manufacturing, which is seen in the diverging production trends between more developed and less developed countries [42].

The NAP was originally formulated mainly to protect domestic producers in Malaysia's automotive industry. Previous research by Iskandar and Ariffin [25] revealed that NAP encourages all forms of innovation among Malaysian automotive suppliers. The study also discovered that, with the exception of process innovation, innovation interacts between NAP and supplier performance. They concluded that for Malaysian automotive vendors looking to boost performance and innovation, NAP is still essential. According to Suffian [53] , by lowering the ethno-nationalist posture, reducing rent-seeking conduct through market discipline, and reevaluating technical catch-up with economic rationality, the total welfare of the car industry can be improved. Despite the up and down in the industry, the automotive industry in Malaysia continues to grow. Therefore, technological advancements in automotive technology, particularly in Malaysia, should align with the National Automotive Policy 2020, which has identified three main directions: Next Generation Vehicle (NxGV), Mobility as a Service (MaaS), and Industrial Revolution 4.0 (IR4.0)[38]. MaaS involves integrating different transportation modes and services into a centralized platform that utilizes digital technology. Meanwhile, IR4.0 utilizes advanced technologies like artificial intelligence (AI), big data analysis, and the Internet of Things (IoT), which are also relevant to NxGV and MaaS [64]. Furthermore, automotive, mobility, and connected technologies have become increasingly crucial for the development of the foundation of cars.

Beside, electric vehicles adoption, continuous development on autonomous vehicles, digitization, Big Data Analytics (BDA), connected cars as the IoT continues to grow, AI, and alternative fuel powertrains such as hydrogen fuel are some of the global trends [24] that have altered the industry landscape by introducing new characteristics and services to vehicle development which Malaysian government has drawn the direction accordingly. Another example of recent trend in automotive technology is lightweighting material. McAuley [37] suggested using polypropylene as doors and instruments panel as this material is possible to be recycled which leads to vehicle lightweighting and sustainable product development. On the other hand, Pervaiz *et al*., [43] introduced a new functional material called cellulose-enabled lightweight automotive composites to improve vehicle fuel efficiency by bringing down vehicle weight to suggested limits.

Automotive technology trend analysis is crucial for both corporate and national decision-makers to gain insights into the developments of automotive technology. Several research were conducted previously by other researchers to identify recent and emerging trends of the automotive industry. Sturgeon *et al.* [51] applied global value chain (GVC) analysis to recent trends in the global automotive industry. Sturgeon *et al.* [52] also then used GVC analysis again to help explain the limits of build-to-order in the industry, the role of regional and global suppliers, the shifting geography of production, and how the characteristics of value chain linkages in the industry favor tight integration and regional production. On the other hand, Timmer *et al.* [56] used World Input-Output Database of international trade to investigate global automotive production.

Sanguesa *et al.* [45] emphasized that the automotive industry has become one of the most significant sectors globally, not only commercially but also in terms of technology growth and research. Therefore, research and development (R&D) implementation is a crucial step in the R&D process. Technology analysis and forecasting aim to generate a comprehensive concept that serves the needs of a future society and the market [3,28]. Politics can affect a national R&D agenda budget, especially during R&D planning [22]. Hence, the allocation of R&D budget should be objective and valid to enable the selection and concentration on promising technology areas.

To develop future potential technology forecasting methodologies, companies and nations have utilized patent analysis as a solution [9,10]. Patents not only contain comprehensive information about developed technology but also provide legal protection for intellectual property rights [41]. Thus, using patent analysis to identify emerging technology is crucial for developing effective management strategies. It can help reduce R&D spending in irrelevant technology domains and design R&D programs to secure core patents. Therefore,
This study aims to examine emerging automotive technologies by analyzing patent data, particularly in Malaysia. The study seeks to identify the players in university-industry research who hold patent ownership and outline the technology trends and inventors with a focus on university-industry collaborations. The outcomes of this investigation will provide valuable information that can serve as a guide for researchers within the automotive industry for further research and obtaining grants.

This paper's structure is organized as follows. Section 2 highlights the significance of patent analysis and the emerging trends in automotive technology. The proposed methodology for identifying patent analysis is described in Section 3. The experimental findings are presented in Section 4, and the conclusions of the study are discussed in Section 5.

2. Literature Review

2.1 Patent Analysis

Patents serve a legal form of protection, a tool to protect investments in scientific and technological research [12,13]. Patents also represent country's or organization's technological progress and are considered as a contractual agreement between the inventor and the government or its designated agency. The use of patent analysis in technology management planning can assist in recognizing the productive technology development trends of competitors and assess the viability of introducing novel technology [1]. By developing patent landscapes and keeping track of them, patent analytics is a particularly effective technique for determining technical trends. Understanding the issues surrounding the study and building of the patent landscape enables one to achieve objective results and correctly understand the development trends of the R&D subject under consideration [5].

In addition, patent analysis facilitates the identification of technological trends and essential technologies by researchers with limited technical expertise [8]. In other words, the analysis comprehended the relationships between patents and identified key patents by constructing a patent network based on keywords used in several patents that were comparable. Examples of patent analysis are patent landscape analysis, validity search, prior art and novelty search, or, freedom to operate or infringement search [7]. Patent landscape analysis aids in revealing patenting trends, examining competitors' R&D over time, keeping track of markets and rapid technological advancements in the field of interest, identifying gaps in R&D, and comparing one's own patent portfolio to identify valuable patents and potential customers for licensing, among other things [18,63]. The validity search is conducted upon patent litigation while prior art and novelty search is conducted during claim drafting. On the other hand, the freedom to operate or infringement search gives product development programs direction and identifies license requirements.

Other examples of patent analysis were by Chang *et al.* [8] who investigated the technological trends in the emerging field of carbon nanotube field emission display by conducting patent analysis and the results indicated the developing tendency of worldwide field emission display production. Venugopalan and Rai [59] applied a natural language processing-based hierarchical technique to identify and classify patents in solar photovoltaics filed in the United States. The results show that the method is able to identify patterns in technological convergence and enable a new way of improving the accuracy of quantifying knowledge spillover between inventions. While Gao *et al.* [19] analyzed the technology life cycle with multiple patent-related indicators quantitatively, Lee *et al.* [29] conducted a technology opportunity analysis based on text mining and quantitative analysis of patent novelty. Patents on thermal management technology of light emitting diode (LED) were taken as sample data and their degree of novelty was calculated. Verhoeven *et al.* [60] in their research measured novelty in recombination and novelty in knowledge origins, novel technological and novel scientific origin by exploring patent-based indicators such as patent classification and citation information. Song *et al.* [49] conducted text mining to the F-term data that classifies patent documents according to the technical attributes of the inventions described within them to identify new technology opportunities and they were able to figure out the difference between target and reference technologies and the links between them. Using patents registered in the USPTO between 2009 and 2013, Yoon *et al.* [65] applied the vector space model, latent Dirichlet allocation (LDA), collaborative filtering, and a visual map called the product recommendation portfolio map to identify and recommend the new application products based on a firm's existing product portfolio. In the research by Niemann *et al.* [39] they defined patent clustering in the course of time as patent lanes and used them to analyze patenting patterns over time with carbon fiber in bicycle technology as sample data. Faria *et al.* [17] took the bioleaching sector as sample data and conducted patent analysis while considering the patent family. Their research results indicate that the evolution of patent production is closely related to the fluctuations in global metal prices. Lee *et al.* [31] analyzed the pattern of technology convergence by using both their 'Association Rules' and 'Link Prediction' to the International Patent Classification (IPC) data of triadic patents and were able to identify the links and convergence pattern between IPC that seemed unrelated before. Lee *et al.* [30] used machine learning (ML) and multiple patent indicators such as patent forward and backward citations, and the number of collaborators and inventors to identify emerging technologies and took patent data from pharmaceutical companies in Korea as sample data. Marku [35] in their patent analysis investigated the technology positioning and links as well as the digital transformation industry's excellent technology structure by analyzing the Derwent classification code. Guderian [20] in the research used smart patent indicators developed by Ernst and Omland (2011) instead of traditional patent variables to identify emerging technologies of smart houses. Santos-Neto *et al.* [46] combined patent analysis and bibliometric analysis to determine technological and scientific trends of monoclonal antibodies and they discovered that there is an important prominence for scientific research in the field as drugs related to it have become essential weapons for the treatment of significant diseases.

Patent analysis that applied automotive industries as sample data were also found in previous research. Song *et al.* [48] conducted a technological characteristics comparison analysis between promising and non-promising technologies and combined it with market attributes which is the analysis of the number of keywords frequently used in customer reviews to identify promising technologies. The research took the automotive industry as sample data and they claimed that the method is suitable for evaluating recently published patents compare to the analysis using patent citation. Ma *et al.* [34] recently investigated the characteristics and trends of an electric vehicle by conducting three types of analysis which were text mining, clustering, and social network analysis to the patents harvested from the DWPI patent database.

2.2 Emerging Automotive Technologies

Emerging automotive technology refers to the application of new and innovative technologies that are currently under development and experimentation to enhance the performance, safety, and environmental impact of vehicles. This covers electric vehicles [45,54], self-driving or autonomous vehicles [36,62], sophisticated driver support systems [2,55], connected vehicles [21,44], and other technologies.

The following discussed the three example of emerging automotive technologies that imply the technology of IR4.0, NxGV, and MaaS;

- Electric vehicles (EVs) is the vehicles that use electric motors powered by batteries to propel themselves. These automobiles do not rely on conventional fuels such as gasoline or diesel, and they generate lower emissions compared to their traditional counterparts. The primary objective of EVs is to mitigate the adverse environmental impact of conventional vehicles that contribute significantly to air pollution and climate change. Some researchers such as Sanguesa *et al*. [45] reviewed previous studies of EVs technologies and concluded that many have discussed about the charging methods of EVs and engine classification with different benefits and challenges. Other recent researches such as Li *et al*. [32] and Liu *et al*., [33] have reviewed big data analytic to predict the battery's heath and proposed machine learning-enable to predict lithium-ion batteroes aging. The aforementioned studies focused on technology related to the IR4.0, particularly AI, ML, and big data.
- Autonomous vehicles (AVs) also known as also known as self-driving cars, utilize various technologies such as sensors and cameras to maneuver roads and traffic without human intervention [6,67]. The primary objective of AVs is to enhance road safety by reducing the number of accidents caused by human errors such as distracted driving or speeding. The implementation of AVs is expected to contribute to the prevention of accidents and ultimately save lives [67]. Christie *et al*. [11] asserted that the past decade has seen the rapid progress of technology in the field of the IR4.0, leading to the testing of multiple prototype autonomous vehicles. According to Daily *et al*. [14] , the adoption of AVs in Asia poses significant challenges. These challenges include the absence of a regulatory framework, adequate infrastructure, compliance with traffic laws, and the practice of autonomous driving. Addressing these challenges is crucial for ensuring the success of AVs in the region and improving the transportation system and driving experience.
- Vehicle-to-everything (V2X) technology allows wireless communication between vehicles, pedestrians, and infrastructure, enabling them to exchange information. The study by Zhou *et al*. [67] emphasized that in their study that V2X technology has the potential to enhance road safety, reduce traffic congestion, and improve the overall driving experience. V2X technology can help improve road safety, reduce congestion, and enhance the driving experience. For example, V2X technology can provide real-time traffic and weather updates, alert drivers to potential hazards, and enable vehicles to communicate with traffic signals to reduce congestion on the road.

Emerging automotive technologies such as EVs, AVs, and V2X are being developed to tackle a multitude of challenges that the automotive industry is facing, from ecological issues to road safety and efficiency. Numerous companies and organizations are collaborating to advance and deploy these technologies with the intention of revolutionizing the way we drive and commute. To enable aforementioned technologies, the following key technology advancements are being discussed:

- Artificial Intelligence (AI) and Machine Learning (ML): AI and ML play a crucial role in the advancement of emerging automotive technology, particularly in the creation of autonomous vehicles. These technologies serve as the primary drivers in enabling vehicles to make real-time decisions and respond to their surroundings by processing data gathered from various sources, including sensors. Song *et al*. [47] conducted a review on the utilization of ML to enhance the energy efficiency of hybrid EVs, while Khayyam *et al*. [27] highlighted the use of AI in identifying factors such as road conditions, weather conditions, traffic patterns, and accident risk for AVs.
- Sophisticated sensors, including radar, lidar, and cameras, play a pivotal role in the advancement of self-driving vehicles. These sensors empower vehicles to "perceive" and comprehend their surroundings, thereby allowing them to make informed decisions based on the acquired information. Elliott *et al*. [15] conducted research on a computer vision-based approach, which is a technique of deep learning for image processing, they utilized input data from sensors and radar for the development of a pedestrian detection system in AV technology.
- Connectivity is another important driver of emerging automotive technology, particularly in the development of V2X technology [23,50]. Connectivity enables vehicles to communicate with other vehicles and infrastructure, connectivity can improve safety, reduce congestion, and enhance the driving experience.

The integration and advancement of these sophisticated technologies have significantly contributed to the emergence of the next era of automotive technology. This innovative technology holds the potential to revolutionize the automotive industry by substantially enhancing the safety, efficiency, and sustainability of vehicles. Moreover, the advent of computational progressions, information, and communication technologies, including AI, ML, and 5G technology, that facilitate connectivity, are indispensable for the development and enhancement of the automotive industry.

3. Methodology

This study aims to examine patented automotive technologies in Malaysia and the universities that hold ownership of these patents. Patent data from Clarivate Derwent Global Patent Data between 2005 and 2022 was collected, manipulated, and analyzed to generate findings. The results were then presented using visualization technique with the help of R programming and ggplot2 library, as depicted in Figure 1, which illustrates the overall procedure employed in this study to investigate the trend of automotive technologies and the patent ownership.

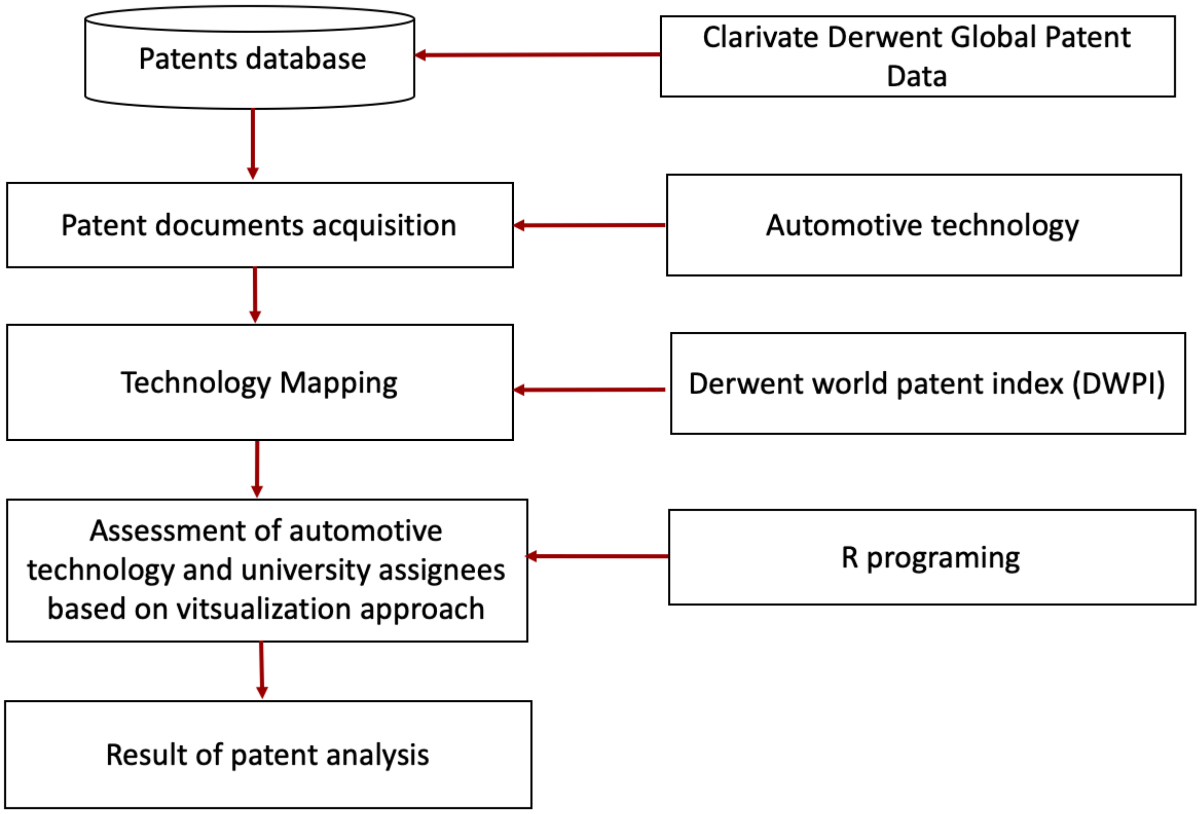

Fig. 1. Adopted methodology [1,28]

The adopted methodology is presented in Figure 1. Firstly, patent documents were extracted, as described in the data acquisition section, and then recorded as a structured dataset in a .csv file. Automotive technologies were assessed and mapped according to DWPI classification, and the university assignees were analyzed to determine which university has the highest number of patents in the collected dataset.

3.1 Data Acquisition and Selection

The patenting of automotive technology has garnered significant interest, given the evolution of technology and the corresponding market demands. In this context, Malaysia was chosen for an in-depth analysis of university-industry R&D, to identify universities as assignees of patent documents. Data was obtained from Clarivate Derwent Global Patent database, using specific keywords such as “automotive” OR “automobile” OR “vehicle” AND “MY”. The period of coverage was from 2004-2022, resulting in 122 records. However, only 78 records were selected under the engineering section, as per the DWPI classification, after excluding patents not relevant to automotive technology.

3.2 Automotive Technology Clustering and Mapping

The 78 records selected for analysis were categorized and assigned to specific DWPI codes that correspond to various subfields of engineering. These codes were represented by the letters P through X, with each letter representing a different group of products or technologies. For example, P represented general products, Q represented mechanical systems such as vehicles, T represented computing and control systems like data processing and trading control, S represented instrumentation, measurement, and testing, U represented semiconductors and electronic circuits, V represented electronic components, W represented communication technologies, and X represented electric power engineering. Further details on these codes can be found in Table 1.

Table 1
DWPI classification code

DWPI classification	DWPI description
P : GENERAL	Human necessities, performing operations.
Q: MECHANICAL	Mechanical Engineering- all
S : INSTRUMENTATION, MEASURING AND TESTING	Includes electrical aspects of medical equipment, photographic and printing apparatus.
T: COMPUTING AND CONTROL	Covers control systems, data recording equipment, computing devices and peripheral apparatus, including construction details.
U: SEMICONDUCTORS AND ELECTRONIC CIRCUITRY	Includes semiconductor components per se, their manufacture and circuitry. Circuits using electronic components are included, e.g. filters and oscillators.
V: ELECTRONIC COMPONENTS	Includes electrical and electro-optical components. Component mounting and construction details. Electrical discharge devices for purposes other than lighting are included.
W: COMMUNICATIONS	Covers telecommunications, audio and video equipment, telemetry/telecontrol and radar, aviation, marine and military systems where electrical details are included.
X: ELECTRIC POWER ENGINEERING	Includes power generation, storage, distribution and utilisation. Electrical details of ground vehicles. Industrial-use patents with significant electrical detail are included. Patents relating to domestic electrical appliances do not have to contain electrical novelty to be included.

3.3 University Clustering and Mapping

Several universities in Malaysia have contributed to the invention and patenting of automotive technology, as evidenced by the data extracted and listed in the "AssigneeCodeUniv" column of the dataset. The university short names, which are publicly known, are summarized in Table 2.

Table 2
Mapping universities' name that patented their products

AssigneeCodeUniv	University short name
UNIV INT ISLAMIC MALAYSIA	IIUM
UNIV KEBANGSAAN MALAYSIA	UKM
UNIV MALAYA	UM
UNIV MALAYSIA PAHANG	UMP
UNIV MALAYSIA PERLIS	UniMAP
UNIV MALAYSIA SARAWAK	UNIMAS
UNIV MALAYSIA TEKNOLOGI	UTM
UNIV MARA TEKNOLOGI	UiTM
UNIV PERTAHANAN NASIONAL MALAYSIA	UPNM
UNIV PETRONAS TEKNOLOGI	UTP
UNIV PUTRA MALAYSIA	UPM
UNIV SAINS MALAYSIA	USM
UNIV TEKNIKAL MALAYSIA MELAKA	UTeM
UNIV TUN HUSSEIN ONN MALAYSIA	UTHM
UNIV UTARA MALAYSIA	UUM
INTEGRATED TRANSPORTATION SOLUTIONS SDN BHD	INTE
FOCUS APPLIED TECHNOLOGIES SDN BHD	FOCU
DB CAPITAL SDN BHD	DBCA

4. Results and Discussion
4.1 Automotive Technology Trend

In Figure 2, the patented automotive technologies are displayed in the bar graph below, and it is apparent that computing and control (T01) is the most frequently invented technology by universities. Following this is measuring instruments (S02) as the second most common, followed by mechanical engineering (Q17) which includes vehicle construction, fitting, propulsion arrangements, and automotive electric (X22) that includes charging and batteries.

The above DWIP classification of T01 represents digital computers electronic data processors, interfaces and programme control as well as internet and mechanical digital computers. S02 indicates engineering instrumentation such as measuring dimensions of weight, flow rate, vibrations, force, acceleration and velocity, gyroscopes, scales, dials, pointers and other details. Q17 classified as vehicle construction, fitting, propulsion arrangements that included car's doors, windows, sunroofs and body finishing part that evident the invention of light weight material. X22 is the third most patented technology that represent automotive electrics for EVs such as batteries and charging capacity and starting motors and generators.

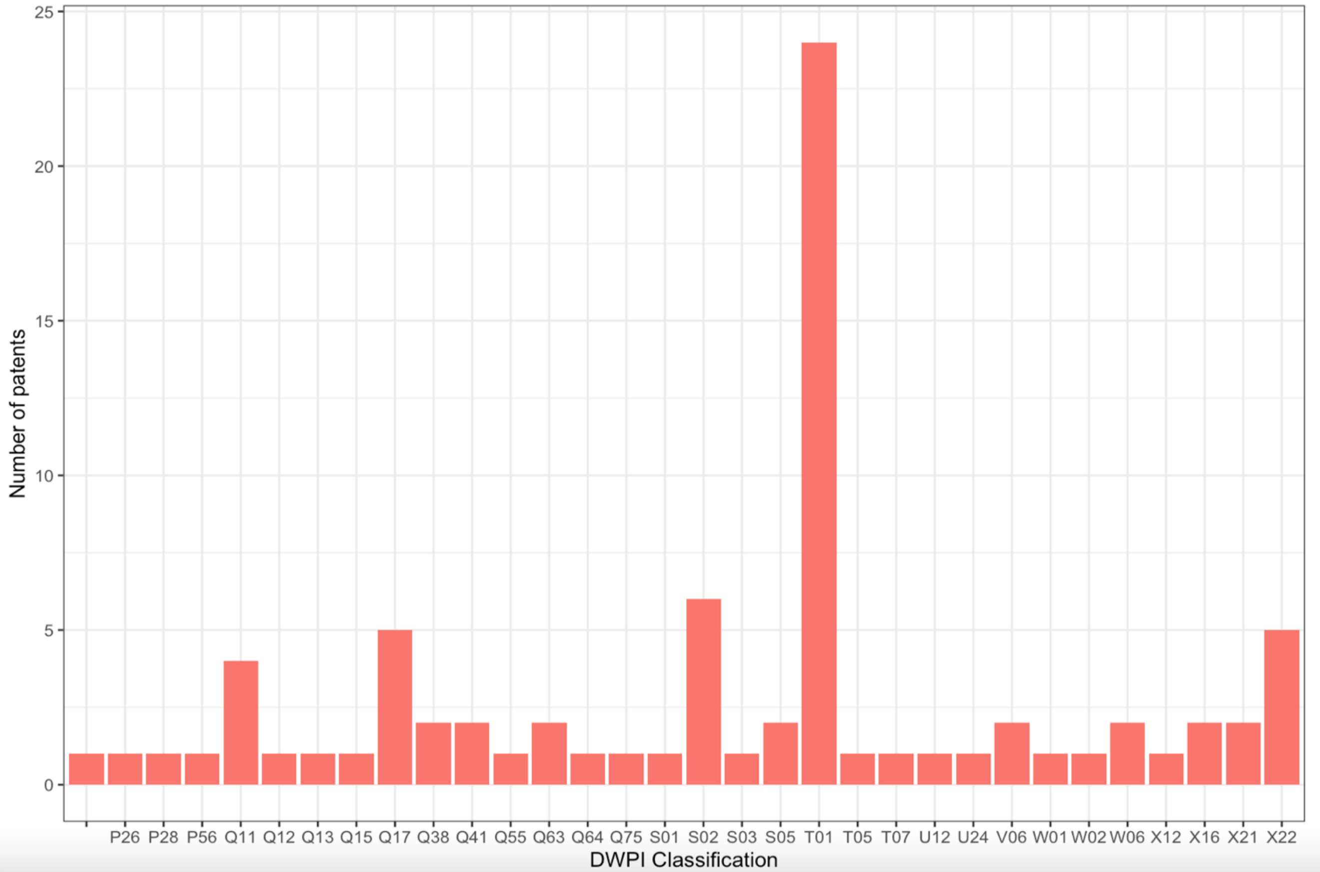

Fig. 2. Patented automotive technology

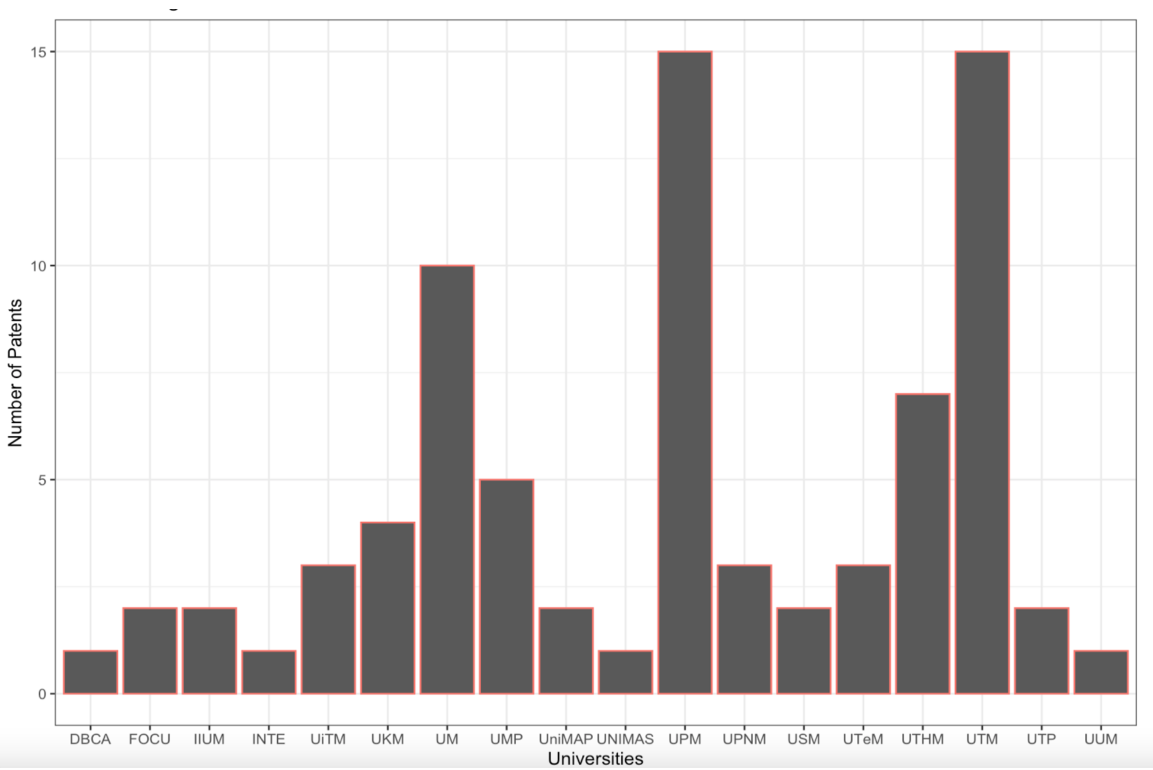

Fig. 3. Number of patented technologies invented by universities

Patent assignee refers to universities that hold the ownership of the aforementioned patented technology. It has been noted that UTM and UPM possess the highest number of patented automotive technologies that is 15 patented technologies, with UM, UTHM, and UMP following closely behind in descending order that is 10, 7, and 5 number pf patented techologies . To put it another way, UTM and UPM lead in terms of patented automotive technology, with UM, UTHM, and UMP ranking second, third, and fourth, respectively (Figure 3).

Futhermore, Figure 4 shows graphical representation of the distribution of patented technology by university from 2005 to 2022. To visualize the data, dark blue represents early patented technologies while light blue represents more recent patented automotive technologies. A large number of universities have contributed to patenting more technologies in recent years, particularly in 2020 and 2011 (vartical view). Moreover, UPM has a record of being an early patent holder in comparison to other universities and has consistently maintained its patenting activities until the present time while UUM is the appeared as the most recent patented owner as recorded in 2022 (Figure 4).

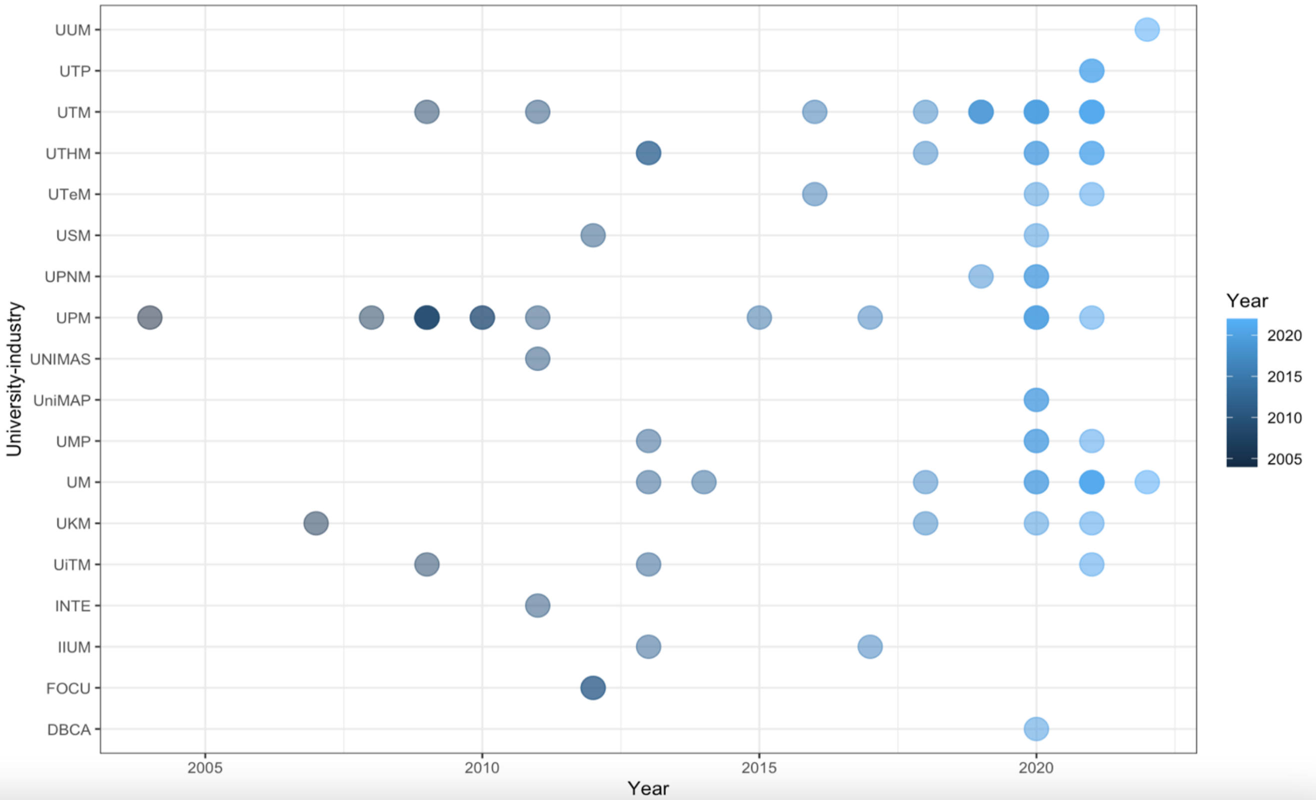

Fig. 4. Patented technologies by universities from 2005-2022

Figure 5 depicts the distribution of patented automotive technology and patent assignee universities from 2005 to 2022. It is apparent that computing and control systems (T01) dominate the automotive domain as many universities have held patents for this technology from the early years to the present. UKM and INTE were the early pioneers in the development of computing and control systems (T01), while UUM has more recently entered the scene with its own patented technology in 2022 (Figure 5).

Figure 6 clearly illustrates the distribution of assignee universities for each technology classification. Computing and control systems are the most frequently patented technology, with 12 assignees including DBCA, INTE, UKM, UM, UMP, UniMAP, UPM, UPNM, USM, UTHM, UTM, and UUM. Automotive electric (X22) is the second most patented technology with 5 patent assignees, namely FOCU, IIUM, UMP, UPM, and UTHM. The third most patented technology is measuring instruments, which has been invented by 4 assignees, namely FOCU, UM, UPM, and UTM (Figure 6).

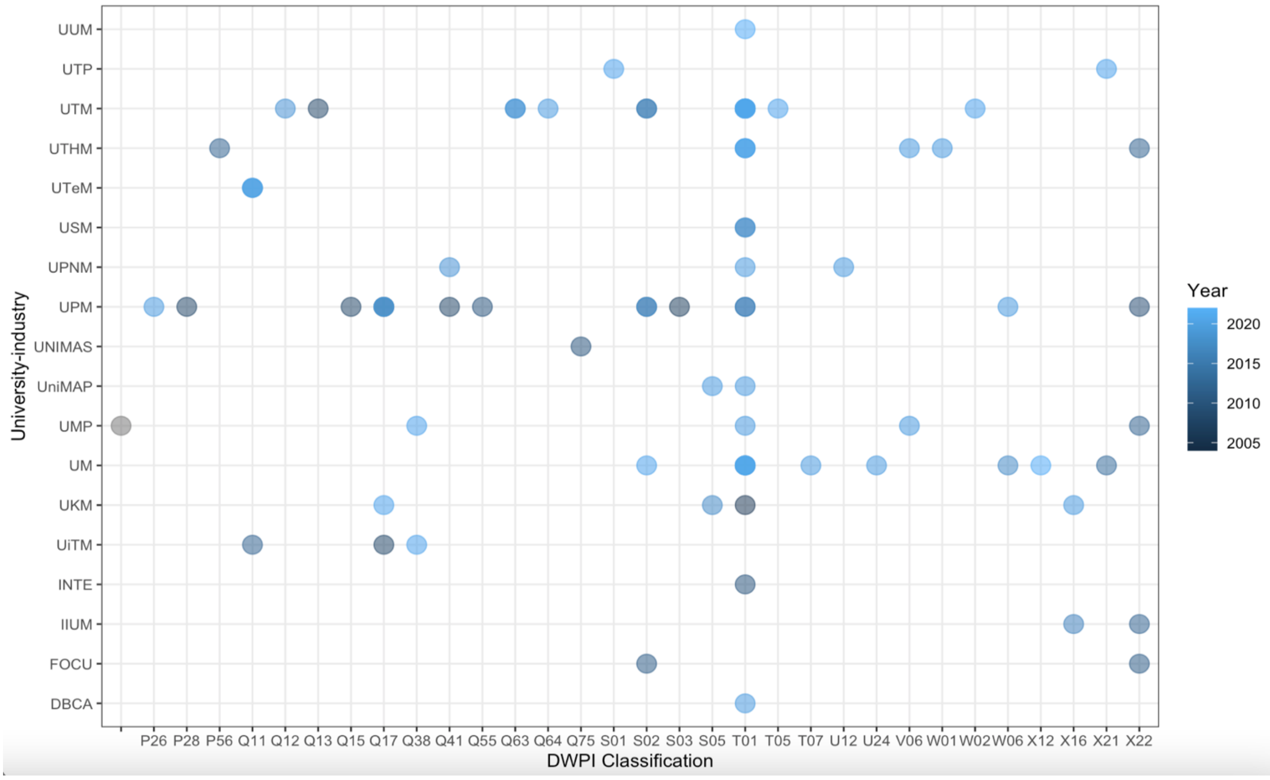

Fig. 5. Patented automotive technology and assignee university from 2005-2022

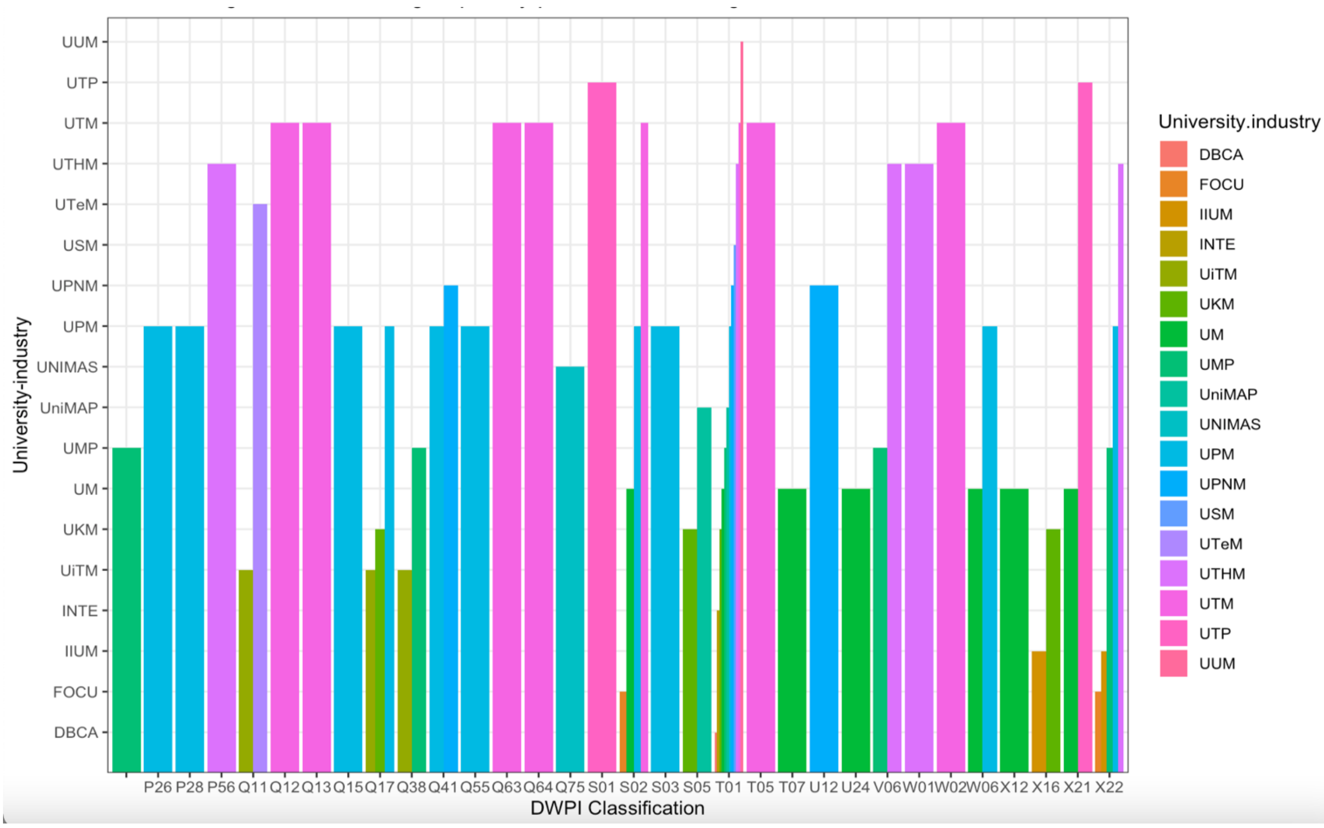

Fig. 6. Patent assignee universities grouped by patented technologies

The automotive industry is facing significant changes due to various factors such as green technology, electric vehicles, self-driving, and mobility as a service. These changes will require car manufacturers to be proactive in adapting to new market trends. In Malaysia, the national car producers will need to establish strategic alliances and cooperate with partner companies in order to remain competitive [4]. This approach will be crucial for Malaysian manufacturers to keep pace with global trends and ensure their long-term success in the automotive industry.

5. Conclusion

This study has identified computing and control systems(T01) as a promising automotive technology, which many universities have patented. Through the use of visualization techniques to analyse patent data, it was found that university research and development efforts are in alignment with the NAP 2020, with a particular focus on AI and IoT, which are IR4.0 technologies aimed at supporting MaaS and NxGV. Moreover, the study has highlighted the top universities with the most patented technologies, namely UTM, UPM, and UM. In summary, patent analysis used visualization technique has effectively identified trends in patented automotive technologies and the universities and industries that have patented their products. This information can be used as a guide by researchers within the automotive industry for their next invention and can serve as a reference for the development of technologies and registration for their intellectual property. This study underlines the importance of tracking patent trends to inform and advance technological innovation in the automotive industry. In future research, it could be beneficial to incorporate different techniques for analysis, such as natural language processing(NLP). This could involve classifying patented documents based on other features, such as the abstract or claim, using unsupervised learning to identify technological classification.

Acknowledgment
The authors would like to express their appreciation for the support of the sponsors with Project Reference Number PY/2022/00225 (Cost Center No. R.K130000.7343.4B750).

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