HIGH VOLTAGE BATTERY
SUPPLY BASE STUDY IN SOUTHEAST ASIA
USING BUSINESS ANALYTICS APPROACH

KITTIYAKORN KHOUNARJ

A THEMATIC SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE IN INFORMATION TECHNOLOGY
SCHOOL OF INFORMATION TECHNOLOGY
SRIPATUM UNIVERSITY
2018

HIGH VOLTAGE BATTERY
SUPPLY BASE STUDY IN SOUTHEAST ASIA
USING BUSINESS ANALYTICS APPROACH

KITTIYAKORN KHOUNARJ

A THEMATIC SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE IN INFORMATION TECHNOLOGY
SCHOOL OF INFORMATION TECHNOLOGY
SRIPATUM UNIVERSITY
2018

THEMATIC TITLE	HIGH VOLTAGE BATTERY SUPPLY BASE STUDY IN SOUTHEAST ASIA USING BUSINESS ANALYTICS APPROACH
KEYWORDS	HIGH VOLTAGE BATTERY, ELECTRIC VEHICLES, SUPPLY CHAIN MANAGEMENT AUTOMOTIVE SUPPLY CHAIN, SOUTHEAST ASIA
STUDENT	KITTIYAKORN KHOUNARJ
ADVISOR	ASST. PROF. PARALEE MANEERAT, PH.D.
LEVEL OF STUDY	MASTER OF SCIENCE IN INFORMATION TECHNOLOGY
FACULTY	SCHOOL OF INFORMATION TECHNOLOGY SRIPATUM UNIVERSITY
YEAR	2018

ABSTRACT

The emergence of Business Analytics has been brought about by the huge upsurge in the amount of available data, increased maturity of business management, and increased focus on fact-based decision making. High-performing businesses utilize analytics to a greater extent than low-performing ones. Electric vehicles bring technological disruptions requiring an entirely different set of suppliers. Suppliers to conventional engine vehicles are experienced on a different technological skill-set compared to the electrical driven vehicles. From the automakers point of view, this new supplier set must be identified and developed from the onset in order to ensure a smooth transition between the two technologies. Business analytics will be employed to identify opportunities and areas for supply chain development. Automakers will be able to use this tool to find new supply sources or to gather new insights from data which will eventually turn into greater and more varied opportunities.

ACKNOWLEDGEMENTS

I would like to thank my adviser Asst Prof Dr Paralee Maneerat, who supported my work and helped me get results of better quality. I am also grateful to the faculty of Information Technology for their patience and support in sharing their time and knowledge.

I would like to thank my fellow students and groupmates for their feedback, cooperation and of course friendship. The encouragements you provided helped me a lot to get things done and accepted nothing less than excellence from me.

Last but not the least, I would like to thank my family: my parents, my husband and to my two sons – Jay and Kit, for supporting me spiritually throughout writing this thesis and my life in general.

Kittiyakorn Khounarj

TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

1.1 Background and Nature of the Problem

The 2015 United Nations Climate Change Conference was held in Paris, France in 2015. In this conference, the centerpieces was the Paris Agreement, a global agreement on the reduction of climate change, representing the consensus of all 196 parties attending the conference. The agreement was to limit global warming to within 2°Celsius compared to pre-industrial levels. During Earth Day the following year, on the 22nd April 2016, the agreement was signed at the UN Headquarters in New York, USA. All signatories began adopting it within their own legal systems. Each country determines plans and reports regularly its own contribution to mitigating global warming. Each country has the flexibility to set their own targets and timetables, and it would appear that this has accelerated the push to adopt electric vehicles as a means to mitigate air pollution. Shown in Figure 1.1 is an illustration of a comparison between total carbon dioxide emissions in 1990 and 2012, for major developed countries. China has shown considerable increase in CO2 emissions during theat period, while most of the other developed countries rmained relatively the same, or more slightly reduced. It also give an idea of the per capita emissions for the same set of countries.

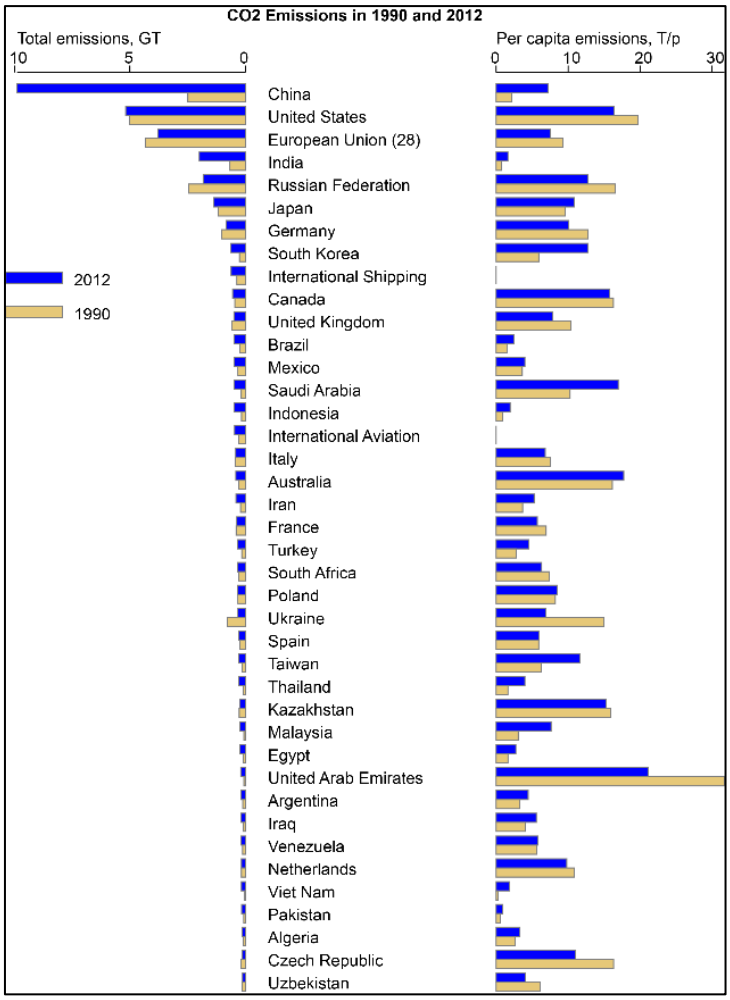


Figure 1.1 Various countries CO2 emissions comparison 1990 vs 2012 (EU EDGAR database)

Governments are focused on the rapid transformation to electric vehicles. Investments are being redirected towards increasing the production capacities of EVs, high voltage battery storage systems and charging infrastructures to support EVs on the road. The transport sector accounts for 14% of total GHG emissions in 2010 (Victor et al., 2014). Of the entire transport sector, close to 30% is accounted for by the personal transport sector (IEA, 2016a).

Faced with growing environmental concerns and government pressures, OEMs must find a way to come up with low emission vehicles. Reducing the weight, building more efficient smaller engines or developing advanced powertrain technologies. This may mean optimizing the current internal combustion engines or developing electric propulsion systems to power electric vehicles. It appears now that OEMs are leaning towards electrification.

Global registrations of electric vehicles exceeded 2 million units in 2016. Although this only accounts for less than 1 percent of global sales, it does prove that the technology is starting to be a viable choice compared to conventional internal combustion powered cars. China and USA are the leading countries in terms of number of vehicles already plying the roads. Norway has the highest penetration, with a market share of 29% as of end-2016. (IEA, 2016b)

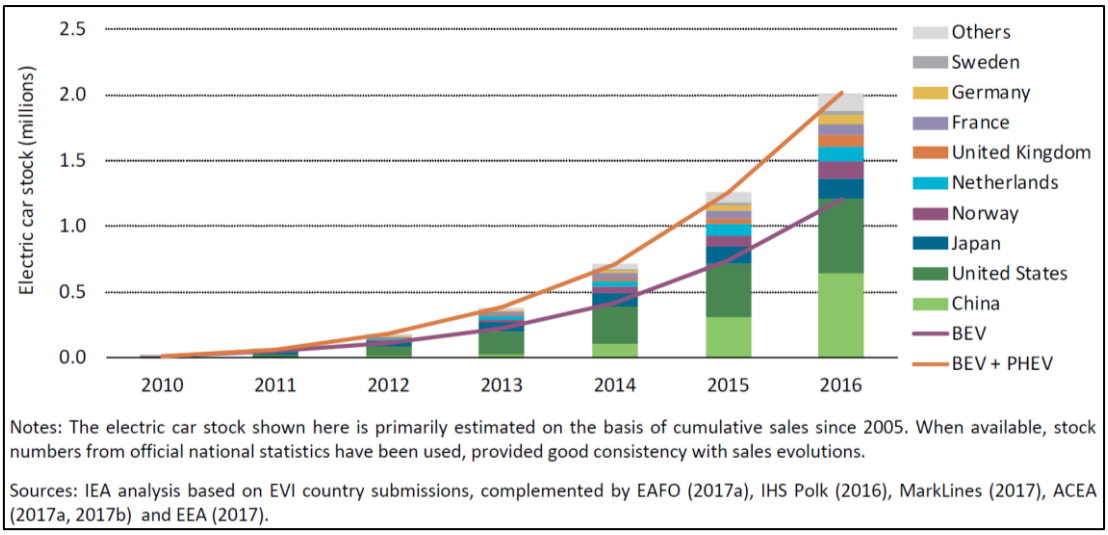


Figure 1.2 Registration of Electric Vehicles 2010-2016 (IEA, 2016)

Given the significant volumes of electrical vehicles that are now achieved, the automotive parts supply situation is also evolving to support these new products in the market. With regards to powertrain and chassis components, electrical vehicles have little in common with internal combustion engine vehicles. New parts have to be designed and manufactured as these ICE parts cannot be carried over to electric vehicles.

Given the disruptive nature of electric vehicle technology against the conventional engine, there is a sense of urgency in the automotive industry to prepare for the next wave. Researches and detailed investigation are all intensely done with the purpose to gather information so that the right strategies can be developed. Suppliers to the automotive supply chain are even more apprehensive about the situation. They must make steps now in order to remain relevant.

The current automotive supply chain, which is a vast, complex and finely tuned network will certainly change to account for this new technology. New entrants will get opportunity to get onboard, while current suppliers who cannot adapt and cannot evolve will eventually be left behind.

In Southeast Asia, the lack of strict CO2 emission regulations means that automakers will not have t make the same level of investments as the developed nations. This approach means that the current conventional designs due to its low cost and the lack of government pressure, may mean that low cost conventional engine vehicles may still be on the roads. However, for Thailand, whose main automotive market is the export market, investments may be done for cleaner, newer technology must be made in order to compete globally.

1.2 Objectives of the Study

The main objectives of the study are as follows:

1. To study the automotive supply chain in Southeast Asia, with special attention to the supplier network of high voltage storage systems
2. To develop and to define a probable supplier network scenario for high voltage battery systems
3. To apply an appropriate business analytics method. In the course of this study, this study create a databank of relevant information and apply a suitable predictive analytic algorithms to define the supplier network of high voltage battery in the region.

1.3 Scope of the Study

Can business analytics be a suitable tool to develop supply chain strategies for new disruptive technologies? Would an experienced and knowledgeable sourcing and supply chain manager be able to use data mining tools to gather information available on the public web and use data mining models to formulate a predictive picture of how a supply network would look like.

This study will strive to make an analysis whether a data warehouse can be gathered and developed from existing available public information. Predictive analytics models are to be developed and applied in supply chain management practices.

The application of these data mining techniques specifically on the subject on making a prediction of supply chain network for lithium-ion based battery cells.

1.4 Benefits of the Study

This study expects to provide significant implications for the academe, supply chain engineers, purchasing, data scientists and policy makers.

Academic benefits

1. This study makes a reporting of the current state of EV technology on a global scale and the state of EV commercialization in a number of global leaders. It proposes a few recommendations to academic community on further areas of research.

2. The automotive parts supply network supporting the EV situation will also be examined in detail. Policymakers may gain new insights and knowledge with some points raised in this study.

Economic benefits

1. Supply chain experts will derive valuable insights in seeing a probable supply network for high voltage battery in Southeast Asia. Strategies can be shaped to conform with the foreseen conditions, thereby, lessening risks from wrong decisions. The risks to make a wrong investment can be greatly reduced.

2. Parts purchasing professionals will benefit from this study by being able to pinpoint potential suppliers from the onset. It takes time and resources to train and develop suppliers. So, it is necessary to be able to identify sourcing points which will be able to be at the right place and time to complement the project supply chain. This way, the best optimal costs can be derived from the onset and investment risks are reduced.

1.5 Word Dictionary

BEV	Battery Electric Vehicle. Electric vehicles that derive propulsion solely from the onboard rechargeable battery which can be plugged-in via an electrical outlet.
Big Data	a holistic approach to manage, process, and analyse the 5Vs (volume, velocity, variety, veracity and value) in order to crease actionable insights for sustained value delivery, measuring performance and establishing competitive advantages
Business Analytics	In this study, it is the process of accessing, aggregating, analyzing and transforming large amounts of data from diverse sources to understand historical and current state of performance or behavior in order to understand business performance and to generate new insights based on data and statistical methods
Data Mining	it is the process of sorting and sifting through large datasets in order to identify patterns and establish relationships to gain insights and provide solutions to underlying situations
EV	Electric Vehicle. Vehicles which are powered by partially by electricity by an electrical motor working in conjunction with a conventional engine, or exclusively electric via an onboard battery.
ICE	Internal Combustion Engines. Vehicles with conventional engines which uses petroleum and emits greenhouse gases during operation.
PHEV	Plug-in Hybrid Electric Vehicle. Electric vehicles with smaller internal combustion engines and a more powerful electric batteries that can be recharged.
Supply Chain	is a system of organizations, people, activities, information, and resources involved in moving a product or service from supplier to customer

CHAPTER 2

2.1 Concepts

A number of different and varying concept have to be brought together in integrated to make this study. This is illustrated on the diagram shown in Figure 2.1. Prevailing environmental issues on climate change and dwindling fossil fuel reserves have accelerated the development and uptake of electric vehicles. Changes on automotive technology will have significant impact on the global automotive supply chain.

Business analytics will be used to create a model to investigate whether this discipline is able to make to provide us on insights with regards to forecasting supply network of high voltage battery systems.

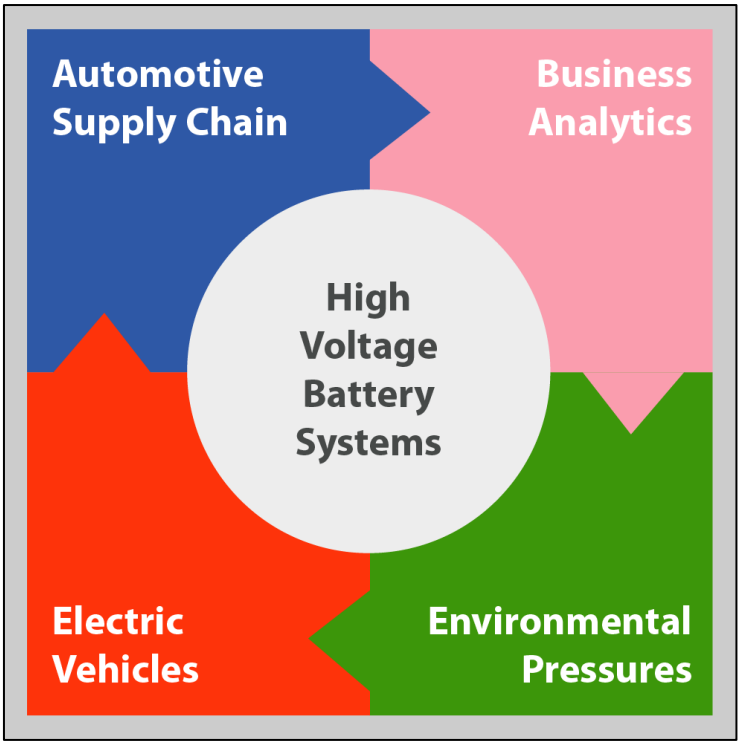


Figure 2.1 Various topics involved in this study

2.2 Automotive Supply Chain

Before we proceed to discuss automotive supply chain, let us establish the basic concepts of supply chain and supply chain management.

Supply Chain is the flow of products and services from raw materials to component makers, from component makers to system module manufacturers, from system manufacturers to OEMs, and from OEMs to the final consumers. It is interesting to note the evolution of the supply chain during the last few decades. Prior to the 1990s, most firms were vertically oriented. The firm's employees performed all functions from product conceptualization thorough final sale and delivery. Typically, all manufacturing was done within the firm and that there was a centralized control of all operations.

In the 1990s, transportation costs dropped and so, manufacturing could be performed anywhere in the world as the transportation overhead is significantly reduced. The manufacturing of the product can now be done in a farther location as the overhead costs attributed to transport is lower. Outsourcing in a lower cost country became a popular choice for manufacturing and assembly. Firms are now able to outsource design/ manufacturing wherever and whenever appropriate. It has gotten to a point where in some cases, a product a user receives will never be handled by an employee of the firm whose name is on its label.

What is Supply Chain Management? Supply Chain Management is a set of approaches utilized to effectively integrate suppliers, manufacturers, warehouses, and stores, so that merchandise is produced and distributed at the right quantities, to the right locations, and at the right time, in order to minimize system-wide cost while satisfying service level requirements. (Feki, Boughzala, & Wamba, 2016)

2.3 Current Situation and Future Outlook

Effective and efficient global supply chain is a must for automotive manufacturers and their suppliers. Supply chain strategies need to be finetuned and adjusted constantly. Real-time information and effective communication across the supply network is critical to optimize and to manage the entire spectrum of the supply network.

One key aspect of the automotive supply chain is a decreased level of vertical integration, simplified production arrangements and focused on core activities. This also results in a reduction of suppliers, as OEMs purchase self-contained, pre-assembled and tested modules which are sent to the OEM assembly line. Systems are organized by OEMs to monitor component purchasing terms worldwide. Global purchasing aims to compare the best terms offered by potential large-scale component suppliers all over the world. Shown in Figure 2.2 is a general depiction of an automotive supply chain. The movement of parts and components may move from different country to another, wherever there are advantages in cost and in transport lead times. In the case below, the raw material supplier may be coming from China, sent to country in Southeast Asia for a component assembly. The components may be assembled to complete system modules in Eastern Europe before being finally delivered in the vehicle assembly in Germany.

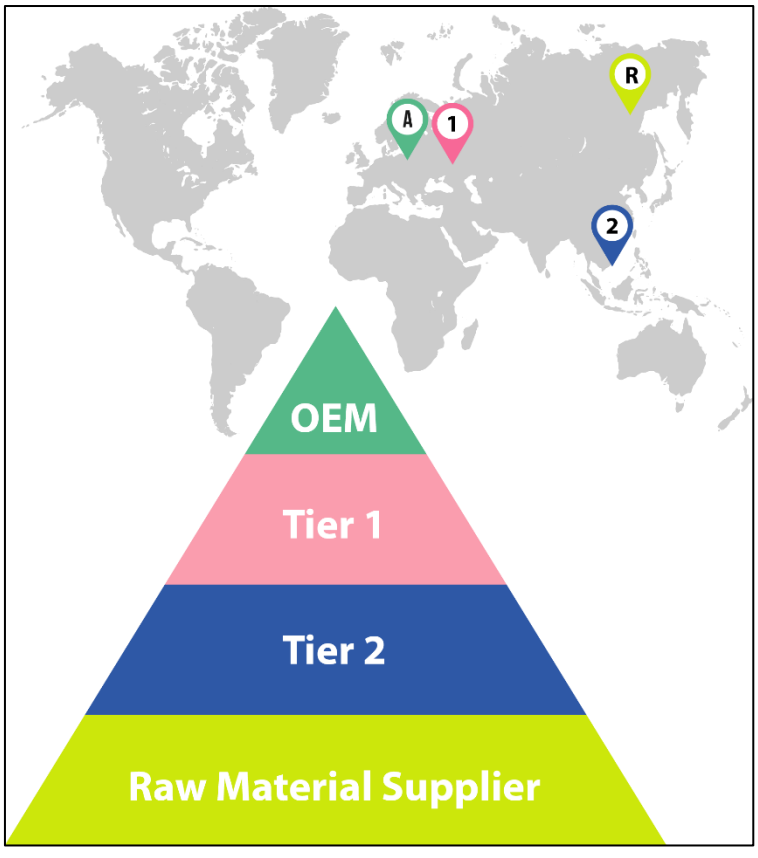


Figure 2.2 Automotive supply chain

2.4 Nature of Automotive Supply Chain

Automotive suppliers are normally tiered onto two levels. Tier 1 suppliers are responsible directly for component design either through co-design for model specific parts or by direct supply of proprietary parts. These first tier suppliers coordinate and receive supplies from sub-tier suppliers. First tier suppliers normally offer technical know-how during the integrating design phase and then becomes component assembler to create one or more of the modules ultimately assembled onto the finished vehicle.

Supplies of components requiring a high level of know-how but relatively low logistic cost compared to sales value, e.g., spark plugs, sensors, will tend to be concentrated in the hands of a few large suppliers.The latter are given the chance to supply all the manufacturing poles to exploit their know-how and to amortize the large investment required. The latter will be responsible for finding the best possible production locations, which do not need to be close to the OEM plant since logistic costs are not a critical factor. This type of situation requires strong central management to ensure that choices are made in the interests of all the poles.

In the case of high know-how and high logistics cost, however, there will only still be one or few suppliers but these will need to be located near the OEM plant. For example, complex modules such as dashboards will have to be supplied from close to the assembly plants due to the high transport and packaging costs involved. Even in this case, suppliers will try to locate only in the main areas where high volumes justify the high investment.The role of the central organization is therefore to negotiate and reach agreements with those suppliers who accept the global business concept setting up in or supplying minor countries too.

Apart from the obvious quality considerations, price is the key choice factor for components requiring modest know-how and logistics costs. The result is a worldwide search for the lowest supply prices available. Here, the central purchasing organization limits itself to comparing prices among existing suppliers and searching for new and more competitive options while the local purchasing structure of the pole chooses the best global supplier on the basis of this data.

The final scenario involves high logistics costs and low know-how. Here, it is essential to choose the best local supplier in order to keep logistic costs down. This requires giving maximum

responsibility to local purchasing managers but requiring them to compare with other poles to try and understand the ideal threshold price.

The four sourcing policies represented show how a global sourcing strategy varies according to the type of module, sub-system or component being supplied. In addition, the roles, responsibilities and relative importance of the central and local purchasing structures will vary according to the different situation and policy.

High voltage battery systems fall within the high know-how high transport cost scenario. This means that suppliers making these systems have to be near the vehicle assembly plants.

2.5 Factors Affecting Global Sourcing Strategies

Emission targets, in view of strengthened focus to alleviate global warming puts pressure on automakers to make the right decision on product platforms, manufacturing locations and supply chain strategies.

Furthermore, energy costs and cost of raw materials continue to increase due to increased global demand. Fluctuating foreign exchange and interest rates add to the challenge and are difficult to hedge.

Trends and factors affecting global sourcing trends are:

- uneven growth
- increased fragmentation
- accelerated volatility

These factors are briefly explained in the paragraphs that will follow.

UNEVEN GROWTH.Demand growth is pegged to be in China, India and Eastern Europe, while the growth curve for Europe, US and Japan is flat and declined. This uneven growth influences decisions on supply chain strategies. OEMs and their supply network need to setup facilities within these countries in order to tap opportunities in these economies.

FRAGMENTATION. Cars segments, such as sedans, vans, pickups and hatchbacks are becoming more niche and specialized. This evolution is meant to capture specialized niche markets, with the aim to get the right product at the right time.

The environmental movement is further influencing the wave of fragmentation by creating a new set of vehicle designs with smaller and more fuel-efficient cars. New powertrain technologies are added to internal combustion engines. This fragmentation result in a more complex supply chain.

ACCELERATED VOLATILITY. Faster shifts in product design, shorter lead time between new technologies, more personalization mean that there are more variations in the product supply chain must be more responsive and flexible. These topics must be built up upfront so that suppliers can react quickly

GLOBALISED LOGISTICS AND INFLUENCE ON GLOBAL SUPLY CHAIN. Globalization involves numerous features, but the following three seem to be the main engine driving global economic integration: (a)internationalization of production accompanied by changes in the structure of production, (b) expansion of international trade in trade and services, and (c) widening and deepening of international capital flows. (Mrak, 2000)

2.6 Transport of Hazardous Materials

Batteries are considered to be hazardous materials. Under certain conditions, there is a risk of explosion or extreme chemical reaction if the internal components are short-circuited. Being hazardous materials, additional and special handling is necessary to move these goods from different countries.

The implication is that high voltage battery manufacturing must be located near the final vehicle assembly facility. This brings another dimensional constraint towards defining a supply chain in that high voltage battery supply must be in the same country as the vehicle assembler. This condition will play a major factor when defining the supply chain network.

2.7 Electrification of Vehicles

Traditional vehicles are typically based on steel bodies and fitted with internal combustion engines. These vehicles are designed and maintained in a production system characterized by modular design and manufacturing strategies for the core technologies fitted in a car.

The integration of alternative powertrain concepts into passenger cars will require completely new components and competencies. In this regard, some small- and medium-sized enterprises will get opportunities to get in the supply network. It is also a challenge for current suppliers as they need to adapt and to evolve in order to stay relevant.

The leaders in the automobile industry – namely Toyota, Nissan, Honda, BMW and General Motors – have been creating new technologies to use renewable energies in their vehicles. According to Dijk, (2010), the market for Hybrid Electric Vehicles became sustainable after 1995. Toyota introduced the Prius to the Japanese market in 1997, while Honda presented the Insight in California the following year. (Cooper & Schefter, 2017) By 2002, the cumulated HEV sales exceeded 100,000 vehicles and reached 1.5 million by 2008.

It is important to delineate the main characteristics of hybrid vehicles, including electric ones. Hybrid vehicles are vehicles with two sources of propulsion. The primary source is the combustion engine, while the secondary source is the high voltage battery. The latter is typically an electric motor, although it can be any other renewable source. (Keim & Kriegel, 1996) The use of hybrid propulsion methods means that carbon emissions can be reduced.

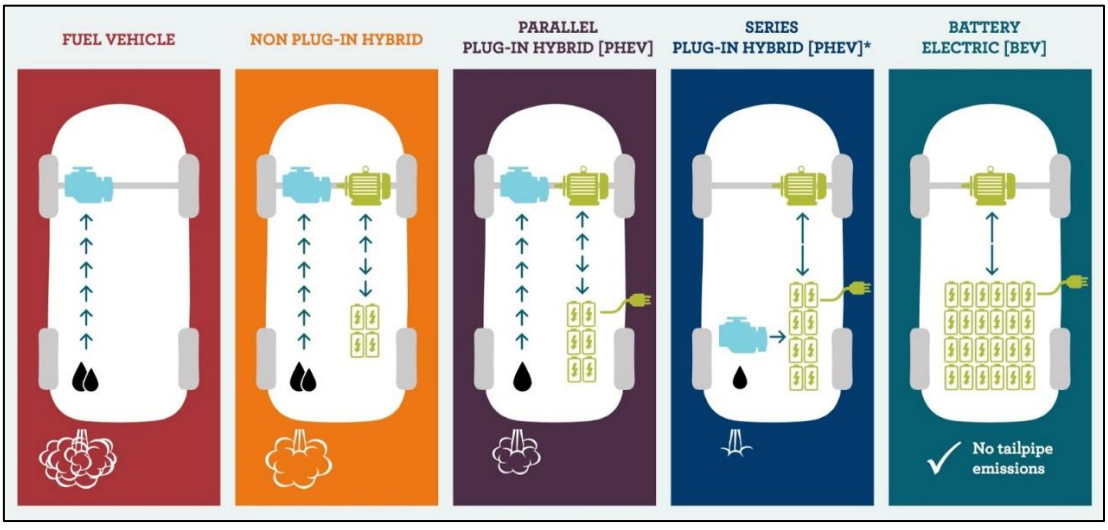


Figure 2.3 An internal combustion engine vehicle and Electric Vehicle propulsion types.

There are various types of electric vehicles, mainly grouped by the amount of influence of electric technology to the powertrain:

1. Full Hybrid Vehicles (HEV). In a full hybrid, the approach is similar to that of the mild hybrid, but the electrical power and stored energy are now high enough to power the car purely from electrical energy. The battery energy available normally limits the range in this mode for a few kilometers.

Batteries for this application must provide more power (to act as the sole source of power in the vehicle) and more energy that for a mild hybrid application. Most applications are still NiMH, but a significant number of vehicles are now lithium-based.

2. Plug-in Hybrid Electric Vehicles (PHEV). The plug in hybrid electric vehicle (PHEV) could be considered to be a full hybrid with the ability to charge the battery from the grid. The vehicle is designed to initially preferentially use the electrical energy from its last charge until this is depleted, at which time it behaves like a full hybrid vehicle.

3. Battery Electric Vehicle (BEV). An EV has the battery as its only source of energy. An EV has zero tailpipe emissions. The power required from an EV battery is the same as for a PHEV, but in an EV as much energy as practical is fitted to give a reasonable range (typically ~100 miles).

2.8 Business Analytics

Visual data mining techniques have proven to be of high value in exploratory data analysis and they also have a high potential for mining large databases. A study done by Keim made a description and an evaluation of visualizations to large databases. The basic idea of visualization techniques is to represent as many data items as possible on the screen with the primary purpose to provide useful visualizations for generating new insights and knowledge (Keim & Kriegel, 1996).

The major goal of this article is to evaluate our visual data mining techniques and to compare them to other well-known visualization techniques for multidimensional data: the parallel coordinate and stick figure visualization techniques. For the evaluation of visual data mining techniques, in the first place the perception of properties of the data counts, and only in the second place the CPU time and the number of secondary storage accesses are important. In addition to testing the visualization techniques using real data, we developed a testing environment for

database visualizations similar to the benchmark approach used for comparing the performance of database systems. The testing environment allows the generation of test data sets with predefined data characteristics, which are important for comparing the perceptual abilities of visual data mining techniques.

First, we noticed that the majority of qualified articles has focused on a framework or conceptual model development, case studies. This result is probably due to the fact that the big data is still on its early stages of development in supply chain. There is a challenge in the field to use other methodologies such as qualitative research, survey and quantitative research to study and measure the impact of big data on supply chain management and performance.

Few authors used theories to study big data in the supply chain. However, several theories such as resources based view theory, contingency theory or systems theory could be mobilized [8, 22]. The determination of theories which can be mobilized for studying big data in supply chain requires further study.

Third, the literature review has allowed detecting business value generated from big data in supply chain. Therefore, it is interesting to develop metrics to measure supply chain performance in big data setting.

2.9 High Voltage Battery

At the heart of the High Voltage Power Systems are lithium-ion cells. Lithium-ion cells, in their most common form, consist of a graphite anode and a lithium metal oxide cathode and an electrolyte of a lithium salt and an organic solvent.

The battery system consists of cells grouped into modules that make up the battery pack, the BMS, and the thermal management system. The power electronics interface the battery system to the motor/generator that is mechanically coupled to an ICE through a transmission. The power electronics typically include high-power switching circuits, inverters, DC–DC converters, and chargers. The transmission either connects both the motor/generator and the engine to the wheels (parallel configuration), only the motor/generator to the wheels (series configuration), or some combination of the two (hybrid configuration). Figure 2.4 shows a typical battery pack.

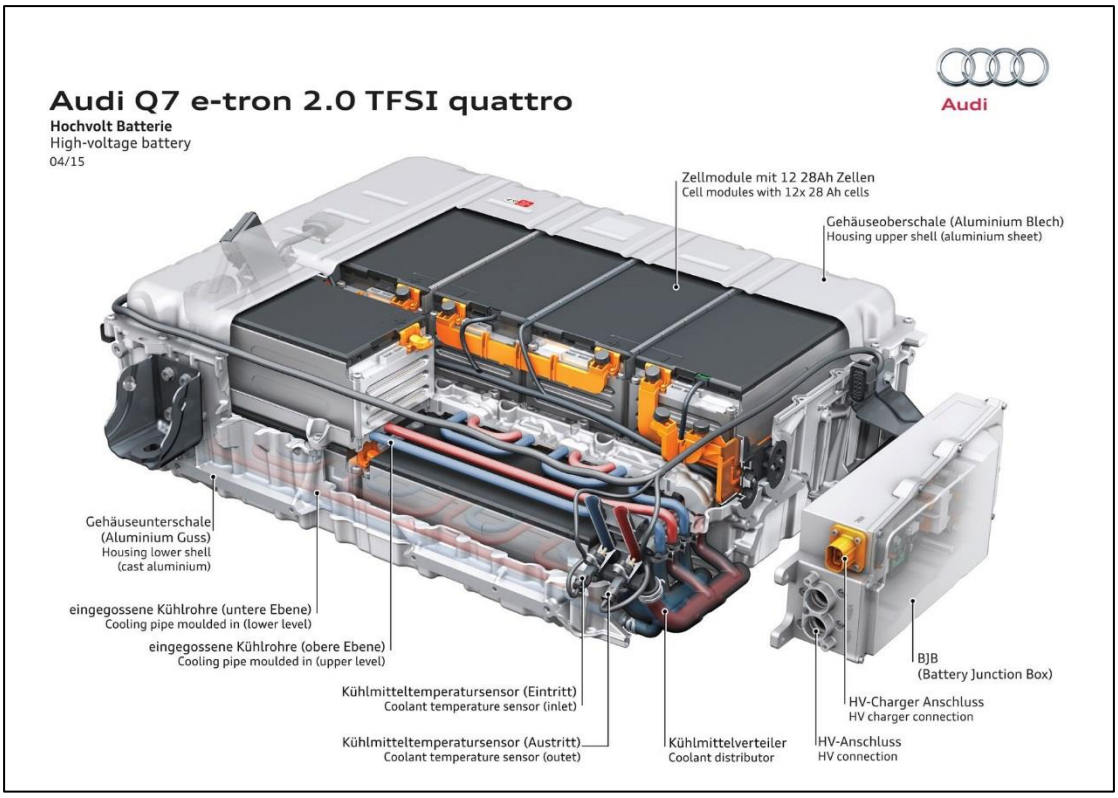


Figure 2.4 A high voltage battery pack

Li-ion batteries are commanding a greater market share owing to their high energy density, which makes them attractive for applications where weight or volume are important (e.g., HEVs). They have a long cycle life (>500 cycles) and low self-discharge rate (<10% per month). High initial cost has limited their use in price-sensitive applications, but new chemistries and economies of scale promise to reduce the cost of Li-ion batteries in the future.

Lithium-ion cells in their most common form, consist of a graphite anode, a lithium metal oxide cathode and an electrolyte of a lithium salt and an organic solvent. Lithium is a good choice for an electrochemical cell due to its large standard electrode potential (-3.04) resulting in a high operating voltage (which helps both power and energy) and the fact that it is the metal with the lowest density (which reduces weight). Figure 2.5 shows a typical battery cell.

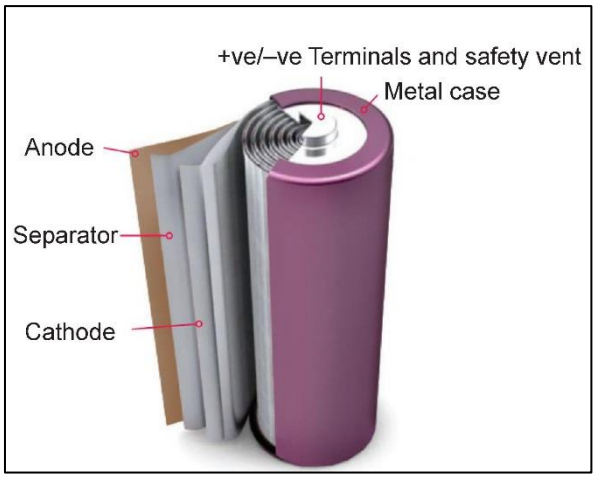


Figure 2.5 A high voltage battery cell. Courtesy of Johnson Matthey (Miller, 2015)

2.10 Literature Review

A number of existing literatures were reviewed and played a critical role in building the concepts presented in this study. The first sections of this study was influenced by researches done on electric vehicle technology and advances on high voltage technology. Next are the sections on big data and its integration to the supply chain. A few papers will be highlighted in this literature review.

Numerous studies are now being made on the subject of big data and its application to supply chain management. A couple of studies worth noting are done by Chae and Waller (2013), which lays the basic concepts on how big data can be used and applied to solve supply chain problems. Chae has outlined some areas of big data analytics and potential applications to supply chain situations. Most companies with established ERP systems already have a centralized data storage system and various data stores where large volumes of the firm's data about products, sales, transactions, orders, and delivery. All these data already form the building block of business analysis, and Business Analytics. (Chae & Olson, 2013)

With the data stored, business value can be extracted and utilized, with the use of data mining techniques and prescriptive analytical techniques for analysis. Prediction of customer and sales, objective function, business constraints can be gleaned from the data. Feedback systems can be set in place and is the basis for Business Process Management, which is a crucial component of BA.

Data Science requires knowledge of the subject aside from having mastery of the quantitative skill. This was the main focus of the study by Waller, where the study puts forward that a broad understanding of supply chain concepts is necessary and is to be used hand-in-hand with the technical data mining tools. These two sets of disciplines are essential for a SCM data scientist. (Waller & Fawcett, 2013)

An extensive search and review of literature showed that a number of studies are already being made on the subjects (Feki, Boughzala, & Wamba, 2016). 15 publications were reviewed, with most of work done centering on framework or conceptual model development, and a few case studies. The authors concluded that this may be due to the fact that the big data is still on its early stages of development in the supply chain. The study likewise pointed out that there are numerous theories such as view theory, contingency theory or systems theory which could be mobilized but which the studies have not yet extensively discussed. Again that authors concluded that this may be due to the early stage of the discipline and that there are still a wide area for further research.

Aside from corporate central data stores, there is also the availability of information from public sources. Social media contains abundant data and the importance and relevance of information found in these public social sources are the subject of numerous study. Twitter is one such medium and studies conducted on the relevancy of information from Twitter hashtags were studied (Chae B. , 2015). Reliability of Twitter data has been the subject of study by George (2016). It is evident that the sheer amount of information and the timely manner that the tweets are sent merits a close attention to verify the usefulness and reliability of Twitter as an information source. The study involved the gathering of Twitter data on the oil industry. This subject was chosen due tot the availability of government information source which can be sused to cerify the Twitter data. Comparative analysis and time precedence analysis between Twitter data and official government data are performed. The author concluded that Twitter data is reliable and timely compared to online announcements, but tend to be focused on a single specific topic rather than a broad multiple topics.

CHAPTER 3

3.1 Research Methodology

This chapter consists of the approach we have taken to undertake the designing the data warehouse and business intelligence system. Due to the fact that the project is based on the business requirement, the implementation will be based on three major phases which is analysis, design and verification. Eldabi et al (2002) argue that the conducting of any type of research should be governed by a well-defined research methodology based on scientific principles.

Data will be collected from various sources which are relevant to the main subject – which is any piece of data which is related to high voltage battery technology.

The following methods were used:

a. Review of existing literature: A number of publications and literature are already available concerning this subject. Relevant titles were collected, collated and used as reference for this research.

b. Field based research: To better understand the nucleus of the project, a bit of a field research is conducted with the view of seeking experts in the general subject.

3.2 Research Design

Business intelligence is the process of obtaining legible information from raw data. It is a tool to consolidate, analyse and visualize vast amounts of data to help users make better business decisions. Business analytics help generate reports and dashboards from raw data which eventually helps to support decision making.

1. This research will outline the steps involved to create a model tracing the gathering of raw data, database backdoor processing of these data, and the processes involved to produce the reports to the relevant stakeholders.

2. The conceptual framework details the conceptual model and the link between Big Data, Business Intelligence, and Business Analytics. The different phases in this conceptual model are:

1. Big Data: identifying the problem that is calling for a decision, and gather intelligence by collecting lots of data (Simon, 1977; McAfee and Brynjolfsson, 2012)

2. Business Intelligence: applications, methodologies, practices, systems, techniques and technologies that analyze the data from phase 1 and helps to test the outcome of available options (Simon, 1977; Chen et. al; 2012)

3. Report generation and dashboard: applications, implementation in accordance with the relevant business case.

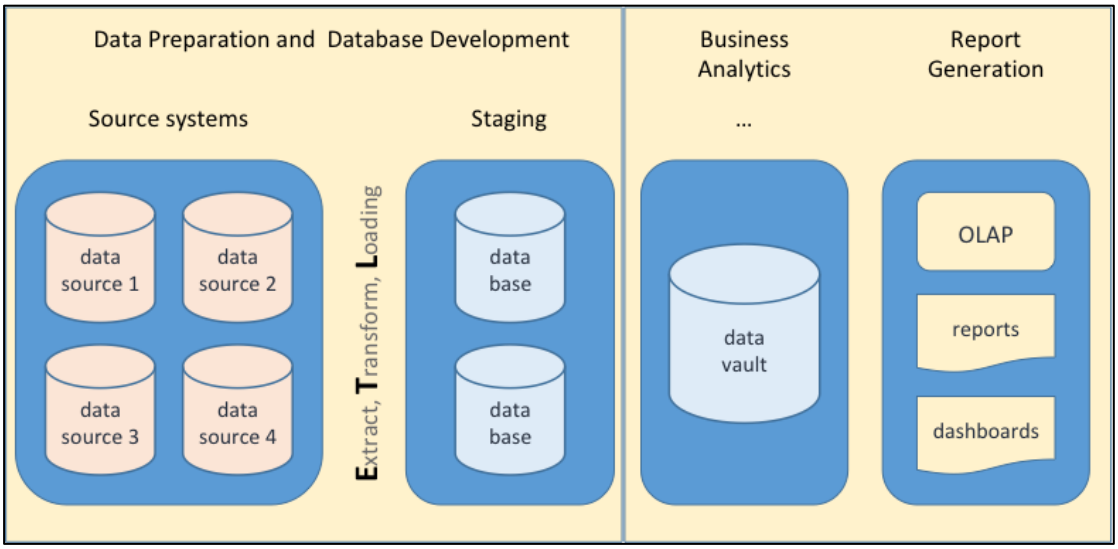


Figure 3.1 Conceptual framework

3.3 Systems Analysis and Research Methods

A research method is a means of collecting data (Bryman and Bell, 2011). In this study, the means of collecting data is literature reviews, interviews, internet search, trade fair, observations

and news events. Collected from all these media, data was gathered, documented, analyzed and findings were documented.

Literature reviews. A literature review was conducted in order to develop a theoretical knowledge base and to direct the empirical study. The majority of information was collected from the websites ScienceDirect, Google Scholar and various websites from leading academic institutions. The main keywords that were investigated were *Business Analytics*, *Big Data*, *Supply Chain Analytics*, *High Voltage Battery*, and *Electric Vehicles*.

Interviews. The three most common interview approaches are structured, semi-structured and unstructured interviews, where structured are more quantitative, and the two latter more qualitative (Bryman and Bell, 2011). The aim is to attain more detailed answers (Bryman and Bell, 2011), they were the choice for this study. As qualitative interview are utilized when there is a great interest in the interviewees' point of view, and the aim is to attain more detailed answers (Bryman and Bell, 2011), they were the choice for this study.

Internet search. The internet was also utilized to gather data and to gain insights on the subject, especially regarding current developments on the topic. The internet provides easy access to new information on the subject, and also as to what is happening in other parts of the world. Internet searches were made in English. It is interesting to note that there is still so much more information that can be accessed should searches be done in non-English language.

Trade exhibits. Trade fairs related to the subject of electrification and high voltage battery were visited. Automotive trade fairs in Hanoi (FBA, March 2019) and Thailand (SETA, March 2018 and TAPA, April 2018), were visited. Supplier information and additional information about supply chain were collected.

3.4 Frameworks and Models for business analytics

Throughout recent years, mainly from the millennium shift and onwards, a number of conceptual frameworks for Business Analytics have been developed by researchers. In one of the pioneering findings, Davenport et al. (2001) present a model for how to build an analytic capability within an organization.

The Business Analytics Model. Laursen and Thorlund (2010) present a different perspective of Business Analytics, as is depicted in Figure 3.3 These authors emphasize the layered and hierarchical nature of analytics, as information requirements flow in a top-down manner, from management in its mainly business-driven environment, and eventually down to IT professionals in the more technically oriented environment. Subsequently, the information supply flows in the opposite direction.

Laursend and Thorlund (2010) explained that in the business-driven environment, management creates and develops an information strategy, which is based on the entity's overall business strategy, such as its vision, mission and objectives. The overall business strategy is usually transformed into a set of key performance indicators which are put in place in order to measure and evaluate the degree of business performance. The strategy and KPIs are subsequently translated into objectives and a framework for the operational level of the business. At this level, the desired behavior of the operational decision makers, and the requirements on information and knowledge to achieve it, are outlined. Business Analytics is about aligning business processes and actions with the overall strategy and business objectives. At this level, operational decision makers, in functions such as marketing, finance and production, can optimize their activities.

3.5 Cross Industry Standard Process for Data Mining CRISP-DM

The CRISP-DM (CRoss Industry Standard Process for Data Mining) Methodology is a multi-industry standard process model used to describe the common processes employed in the data mining field (Wirth & Hipp, 2000). This methodology breaks down the process into six major distinct grouping, as described in Figure 3.2

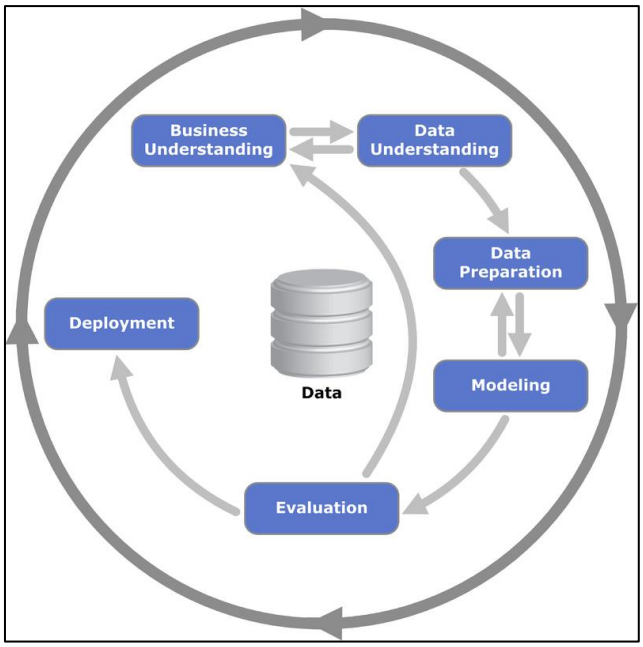


Figure 3.2 Process diagram showing the relationship between the different phases of CRISP-DM

The sequence of the phases are distinctly grouped but can be loosely implemented based on the specific situation. The implementation is not strict and may move back and forth between different phase depending on the suitability. The arrows in the process diagram indicate the most important and frequent dependencies between phases. The outer circle in the diagram symbolizes the cyclic nature of data mining itself.

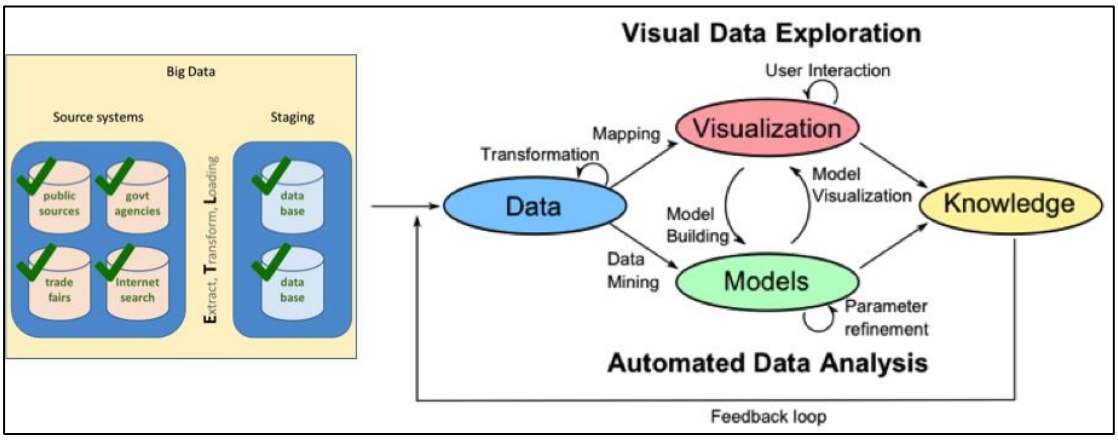


Figure 3.3 Data Transformation Process

A data mining process continue to spiral on after a solution has been deployed. New insights may be gained and new lessons learned during the process, which can trigger new, more focused business questions. Subsequent data mining processes most often build and do benefit from previous experiences and implementations.

Following are the various CRISP- DM phases and some explanation of the activities involved in each phase.

Business Understanding

The focus in this particular step is to gain understanding of the objectives and requirements of the stakeholder from a business perspective. At this step, the objectives are consolidated into a data mining problem, with clear targets and implementation plan formulated. This process step is broken down further into several sub-steps, namely:

a. determination of business objectives
b. assessment of situation
c. determination of goals, and
d. generation of project plan.

Data Understanding

In this process step, initial data collection and familiarization of the data is the main focus. Identification of data quality problems, initial insights into the data and detection and collection of interesting data sets are the main activities in this phase. It is further broken down into:

a. collection of initial data
b. description of data
c. exploration of data, and
d. verification of data quality.

Data Preparation

This covers all activity involved in constructing the final dataset. It is further broken down into:

a. collection of initial data
b. description of data
c. exploration of data, and

d. verification of data quality.

Modelling

This covers all activity involved in selecting and applying various modeling tools. It is further broken down into:

a. selection of modeling technique
b. generation of test design
c. creation of models, and
d. assessment of generated models.

Evaluation

After building one or more high quality models, the models are valuated from business objective perspective and review of the steps executed to construct the models is performed. It is further broken down into:

a. evaluation of the results
b. process review
c. determination of the next steps

Deployment

This stage involves organizing and presenting the discovered knowledge in a user-friendly way. It is further broken down into:

a. planning of the deployment
b. planning of the monitoring and maintenance
c. generation of the final report, and
d. verification of data quality.

The following tables below illustrates the study research methodology, inputs and outputs for each major step.

Table 4-1 Research Methodology

Study Steps	Process Steps	Output
Step 1 To study and identify the relevant concepts and IT tools to create a data source for defining the supply network to support the manufacture of high voltage battery in Southeast Asia	Step 1.1 Study concepts, theories and basic foundations related to high voltage battery technology and its applications	Data source for analysis to describe the supplier network for high voltage battery manufacturing
	Step 1.2 Study concepts, theories and basic foundations related to big data and data analytics	
	Step 1.3 Define a list of data relevant to create a data mart for data analysis	

Table 4.2 (continued)

Study Steps	Process Steps	Output
Step 2 To develop the conceptual framework on the harvesting, gathering, extraction, transformation and loading of data to database	Step 2.1 Design the working model on harvesting, extracting, transforming and loading data onto databases (ETL functions)	A working datamart / data warehouse containing the relevant data and information
	Step 2.2 Focus to apply on using the appropriate knowledge Discovery Process KDP, relevant to the study	
Step 3 To analyse and synthesize information from the data by using business analytics through the creation of dashboards and reports	Step 3.1 To use and to apply data analytics in order to analyse the data and generate reports and dashboards	Dashboards and reports

CHAPTER 4

4.1 Research Implementation

4.1.1 Generate Business Understanding

The first phase as defined by CRISP-DM where business objectives and stakeholder requirements are studied considered and formulated, are defined in the first three chapters of this study. Chapter 1 has defined the objective of the study, which has been expanded in Chapter 3 where the business objectives of defining a supply chain network for high voltage battery is defined using business analytics.

The situation is assessed and defined further in Chapter 3, where the business environment and existing atmosphere is stated and defined. Again, the concepts of supply chain management, situation of automotive industry toward increasing vehicle electrification, and high voltage battery technology had been expanded and defined as well.

The project plan and activities had been defined as well, with the study implementation phase to begin and end within the confines of the academic semesters of this course.

4.1.2 Generate Data Understanding

This implementation phase concerns initial data collection and data familiarization. The basic data requirements are penned out and a list of relevant data needed to create a datastore and a datamart are defined.

In the particular case of this study, a list of potential suppliers located in the major southeast Asian countries, along with their general corporate information needed to be gathered and inputted onto a specific database for our study. As output for this phase, a data source must be gathered and established in order to provide a base for visualization and modeling techniques, which will eventually provide new insights and realizations to further fuel new strategies and activities.

A data dictionary has been defined listing the data needed, its meaning, relationship to other data and its format.

Table 4.1 Data Dictionary

Attribute Name	Data Type	Key	Constraints	Description
ENTRYID	INT	PK	NOT NULL	Entry Number
TOP100	CHAR(1)			Top 100 Global Supplier
SUPP_NM	CHAR(128)	FK	NOT NULL	Supplier Name
WEBSITE	CHAR(128)			Supplier website address
MNPROD	CHAR(64)		NOT NULL	Main product commodity
SBPROD	CHAR(64)		NOT NULL	Sub product commodity
INDUSTRY	CHAR(32)			Main industry where supplier belongs
MNPROCESS	CHAR(32)		NOT NULL	Primary manufacturing process at the supplier
MNMATL	CHAR(32)			Primary raw materials used by the supplier
TECHCAP	CHAR(12)			Supplier technical capability
PR_COMPLX	CHAR(12)			Product complexity which supplier is capable
OWNRSHP	CHAR(24)			Type of corporate entity
NATIONAL	CHAR(24)			Nationality of major shareholder
PROVINCRA	CHAR(24)			Province where supplier is located
COUNTRYRA	CHAR(24)			Country where supplier is located
POSTCODE	CHAR(12)			Postcode of supplier
YEAREST	CHAR(4)			Year established

Table 4.2 (continued)

Attribute Name	Data Type	Key	Constraints	Description
EMPLOYNBR	INT			Number of persons employed
REGCPTL	INT			Registered Capital in USD
RVNUE17	INT			2017 Sales Turnover in USD

Data sources considered for this study would be information on manufacturing firms which directly or indirectly supply parts or services to the automotive industry. The author assumed that this data would be available to both government agencies and privately owned companies working within the automotive industry. A list of these agencies were listed and were requested for information.

The table below shows the agencies – governmental and private sector – contacted and interviewed to gather information on manufacturing companies.

Indonesia	Gaikindo / GIAMM
Malaysia	Malaysia Automotive Institute
Philippines	Board of Investments
Thailand	Thai Auto Parts Makers Association / Board of Investments
Singapore	Economic Development Board / Enterprise Singapore
Vietnam	Ministry of Trade / SEDEC

Data on suppliers has been gathered from public sources, mainly through interviewing various government agencies and trade associations in the various Southeast Asian countries.

Data gathered where in various differing formats – spreadsheets, pdf, text files, and paper hardcopy. Information was also obtained from the internet – in html format.

4.1.3 Prepare Data

Having obtained the data in a diverse format, the main activity at this point would be to upload all the data into a central data store. Data in hardcopies and pdf files have to be manually encoded. Information from Excel spreadsheets is also inspected and the formats synchronized and aligned with the other data.

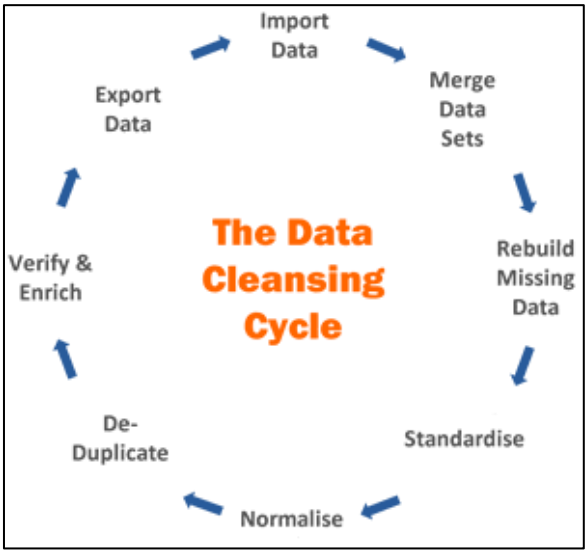


Figure 4.1 Data Cleaning Process

In actuality, the data received from the various sources are shown in Table 4.3:

Table 4.3 Data Dictionary

Indonesia	Gaikindo / GIAMM	membership publications, CD-ROM
Malaysia	Malaysia Automotive Institute	Excel spreadsheet
Philippines	Board of Investments	Hardcopy list
Thailand	Thai Auto Parts Makers Association / Board of Investments	Member directory publication
Singapore	Economic Development Board / Enterprise Singapore	Excel spreadsheet

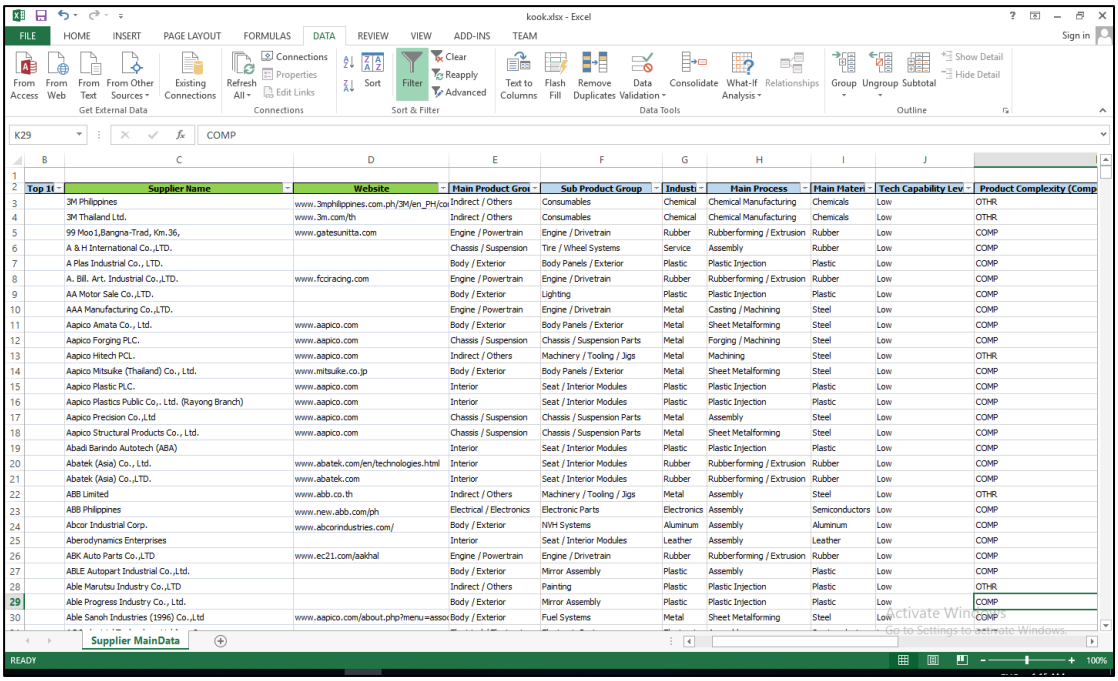
Vietnam	Ministry of Trade / SEDEC	Publications, Member directory
Internet	Various websites	HTML pages, pdf files
Suppliers		Company profiles in pdf, hardcopy

In line with the data cleansing cycle shown in Figure 4.1, the primary step would be to import the data onto a single data location, whether this location will be an Excel spreadsheet, or a Microsoft SQL database, or in any defined format. Regardless of the type of format, would not be relevant as long as the data are homogeneous and easily accessible. For ease of data input and easily accessible, Excel spreadsheet was chosen to be the initial data location for all the data obtained thus far.

Data entry encompasses the act of transferring data from the physical state into electronic format. The nature of the data that was obtained in this study, being in hardcopy in paper and in electronic format (as pdf files), necessitates a manual input to build the database.

Once the input was done, each field was inspected and datatypes were cleaned, corrected, and adjusted. Some corrections were done at this stage.

The data cleansing cycle was applied a few times until the relevant fields were completed.



Top 1(	Supplier Name	Website	Main Product Grou	Sub Product Group	Industi	Main Process	Main Materi	Tech Capability Lev	Product Complexity (Comp
	3M Philippines	www.3mphilippines.com.ph/3M/en_PH/co	Indirect / Others	Consumables	Chemical	Chemical Manufacturing	Chemicals	Low	OTHR
	3M Thailand Ltd.	www.3m.com/th	Indirect / Others	Consumables	Chemical	Chemical Manufacturing	Chemicals	Low	OTHR
	99 Moo1,Bangna-Trad, Km.36,	www.gatesunitta.com	Engine / Powertrain	Engine / Drivetrain	Rubber	Rubberforming / Extrusion	Rubber	Low	COMP
	A & H International Co.,LTD.		Chassis / Suspension	Tire / Wheel Systems	Service	Assembly	Rubber	Low	COMP
	A Plas Industrial Co., LTD.		Body / Exterior	Body Panels / Exterior	Plastic	Plastic Injection	Plastic	Low	COMP
	A. Bil. Art. Industrial Co.,LTD.	www.fciracing.com	Engine / Powertrain	Engine / Drivetrain	Rubber	Rubberforming / Extrusion	Rubber	Low	COMP
	AA Motor Sale Co.,LTD.		Body / Exterior	Lighting	Plastic	Plastic Injection	Plastic	Low	COMP
	AAA Manufacturing Co.,LTD.		Engine / Powertrain	Engine / Drivetrain	Metal	Casting / Machining	Steel	Low	COMP
	Aapico Amata Co., Ltd.	www.aapico.com	Body / Exterior	Body Panels / Exterior	Metal	Sheet Metalforming	Steel	Low	COMP
	Aapico Forging PLC.	www.aapico.com	Chassis / Suspension	Chassis / Suspension Parts	Metal	Forging / Machining	Steel	Low	COMP
	Aapico Hitech PCL.	www.aapico.com	Indirect / Others	Machinery / Tooling / Jigs	Metal	Machining	Steel	Low	OTHR
	Aapico Mitsuike (Thailand) Co., Ltd.	www.mitsuike.co.jp	Body / Exterior	Body Panels / Exterior	Metal	Sheet Metalforming	Steel	Low	COMP
	Aapico Plastic PLC.	www.aapico.com	Interior	Seat / Interior Modules	Plastic	Plastic Injection	Plastic	Low	COMP
	Aapico Plastics Public Co,. Ltd. (Rayong Branch)	www.aapico.com	Interior	Seat / Interior Modules	Plastic	Plastic Injection	Plastic	Low	COMP
	Aapico Precision Co.,Ltd	www.aapico.com	Chassis / Suspension	Chassis / Suspension Parts	Metal	Assembly	Steel	Low	COMP
	Aapico Structural Products Co., Ltd.	www.aapico.com	Chassis / Suspension	Chassis / Suspension Parts	Metal	Sheet Metalforming	Steel	Low	COMP
	Abadi Barindo Autotech (ABA)		Interior	Seat / Interior Modules	Plastic	Plastic Injection	Plastic	Low	COMP
	Abatek (Asia) Co., Ltd.	www.abatek.com/en/technologies.html	Interior	Seat / Interior Modules	Rubber	Rubberforming / Extrusion	Rubber	Low	COMP
	Abatek (Asia) Co.,LTD.	www.abatek.com	Interior	Seat / Interior Modules	Rubber	Rubberforming / Extrusion	Rubber	Low	COMP
	ABB Limited	www.abb.co.th	Indirect / Others	Machinery / Tooling / Jigs	Metal	Assembly	Steel	Low	OTHR
	ABB Philippines	www.new.abb.com/ph	Electrical / Electronics	Electronic Parts	Electronics	Assembly	Semiconductors	Low	COMP
	Abcor Industrial Corp.	www.abcorindustries.com/	Body / Exterior	NVH Systems	Aluminum	Assembly	Aluminum	Low	COMP
	Aberodynamics Enterprises		Interior	Seat / Interior Modules	Leather	Assembly	Leather	Low	COMP
	ABK Auto Parts Co.,LTD	www.ec21.com/aakhal	Engine / Powertrain	Engine / Drivetrain	Rubber	Rubberforming / Extrusion	Rubber	Low	COMP
	ABLE Autopart Industrial Co.,Ltd.		Body / Exterior	Mirror Assembly	Plastic	Assembly	Plastic	Low	COMP
	Able Marutsu Industry Co.,LTD		Indirect / Others	Painting	Plastic	Plastic Injection	Plastic	Low	OTHR
	Able Progress Industry Co., Ltd.		Body / Exterior	Mirror Assembly	Plastic	Plastic Injection	Plastic	Low	COMP
	Able Sanoh Industries (1996) Co.,Ltd	www.aapico.com/about.php?menu=asso	Body / Exterior	Fuel Systems	Metal	Sheet Metalforming	Steel	Low	COMP

Figure 4.2 The Final Dataset

4.2 Modelling / Visualisation

In order to provide the necessary insights and knowledge generation, a visualization software is needed to organize and generate visualizations. There are a number of software readily available for corporate users.A number of these software applications have to be purchased (Marr, 2017) while some software can be downloaded and used freely (Rist, 2016).

Table 4.4 shows the different visualization software available as of the time of the study.

For Sale	Free Download / Use	
Tableau	Tableau Public	Chartbuilder
Qlikview	Tableau Gallery	Open Refine
FusionCharts	Microsoft Power BI	
HighCharts	Openheatmap	
Datawrapper	Weave	
Plotly	Leaflet	
Sisense	Silk	

In the course of this study, Power BI by Microsoft has been used to the visualization. The researcher has downloaded and used a free trial package. This software was introduced to the researcher during one of the courses in the university's master study courses.

The following pages would feature the different visualizations generated from Power BI, the datasets used in the visualization, and the subsequent analysis derived from the diagrams.

4.2.1 Bar charts

Considered a classic as this may be deemed as the most prevalent visualization graphic used. The bar chart uses horizontal or vertical bars to show discrete, numerical comparisons across categories. One axis of the chart shows the specific categories being compared, which the other axis represents the discrete value scale.

In the following visualizations, we needed to get an overview of the different raw materials used by the various suppliers in Southeast Asia. What would be the most prevalent materials used and which country uses these materials most?

A STACKED COLUMN CHART is used and attribute names COUNTRYRA and MNMATL were inputs to the visualization, shown in Figure 4.3

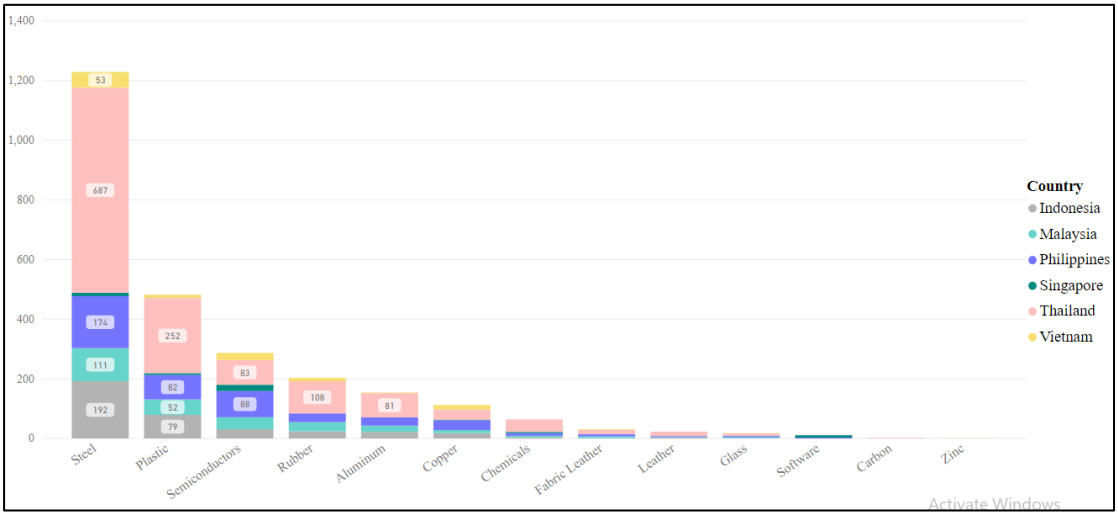


Figure 4.3 Bar chart visualization

From the chart, we can see that steel is the most used raw material with Thailand being the country which uses this raw material most. To cite a statistic, 687 companies in the dataset are Thai suppliers utilizing steel as their main material used in manufacturing.

The same stacked column chart is used, but filters were applied, generating the chart in Figure 4.4 In this particular case, the country filter was applied with only data from Thailand shown in the visualization.

This charts gives a insight on the main materials used by Thailand based automotive suppliers.

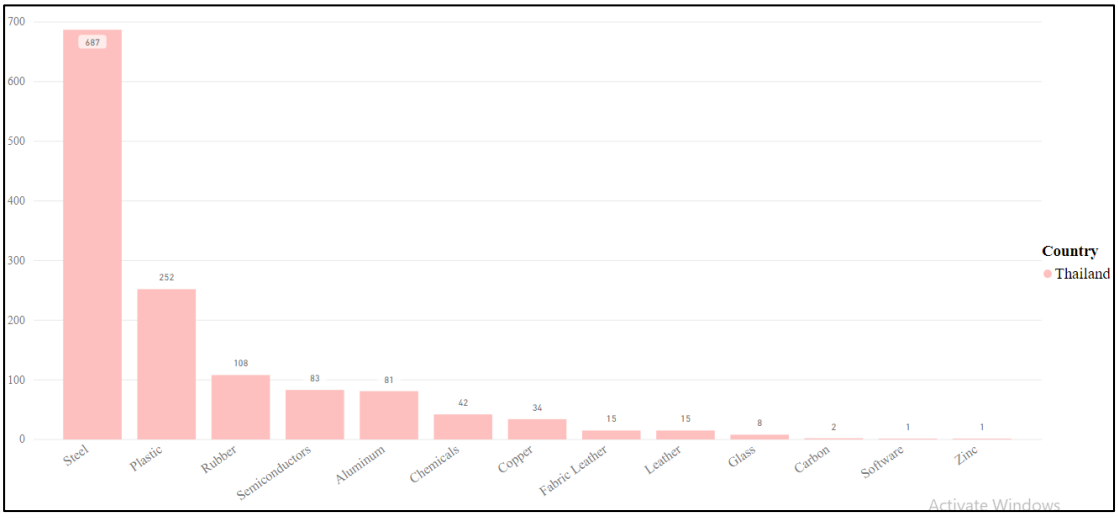


Figure 4.4 Bar chart visualization – Thailand-based suppliers only

In Figure 4.5, the country filter for applied, only this time – Vietnam-based suppliers were highlighted and shown in the chart.

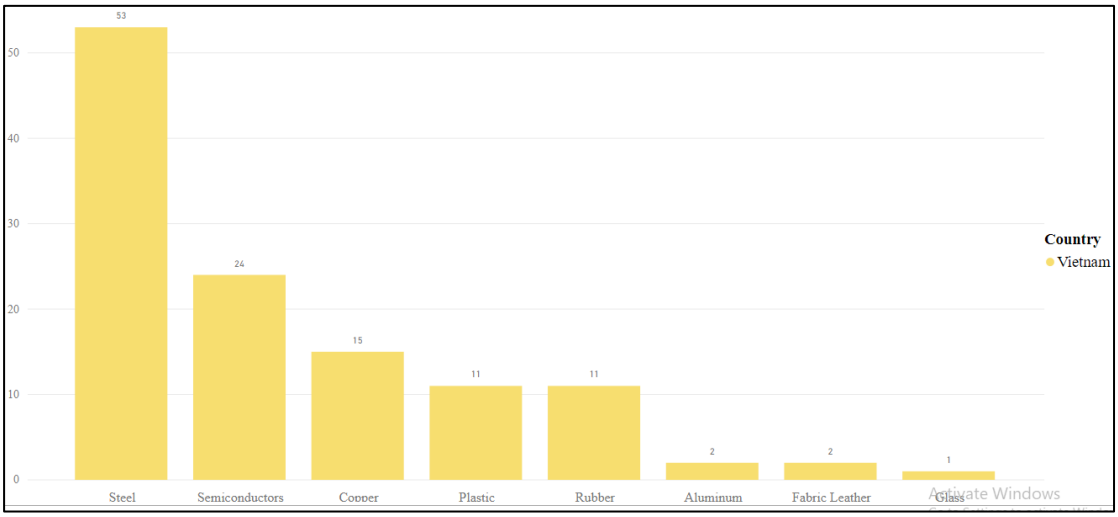


Figure 4.5 Bar chart visualization – Vietnam based suppliers only

4.2.2 Maps

Figure 4.6 shows a visualization MAP. This visualization shows where each data point is geographically located. This visualization provides two main information points which is to provide a visual idea of where the data point is located in the world, and provides a positional reference to other data points. This visualization also provides insight on the frequency and the concentration of data points in a given location.

The data points required in visualization are locations points. These data may either be addresses, or GPS points, or global coordinates latitude and longitude.

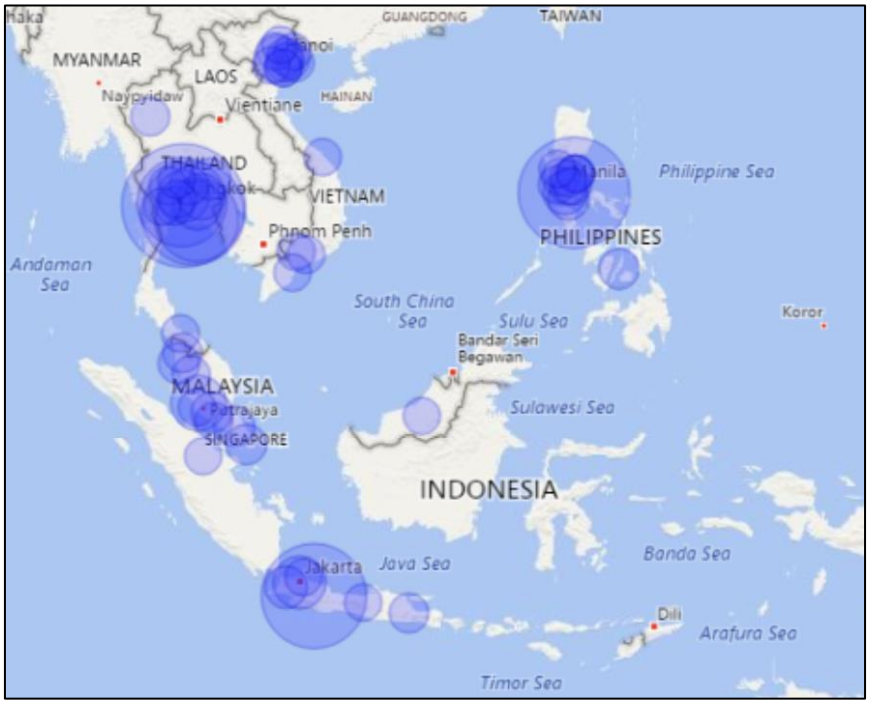


Figure 4.6 Automotive supplier concentrations in Southeast Asia

Figure 4.6 shows a map depicting the locations of all the suppliers in the data warehouse. In order to make this visualization, the following fields were considered: COUNTRYRA, PROVINCRA. POSTCODE would also be a solid dataset to be used. However, the application of postal codes are still being implemented in Vietnam, as of the time this research is done, and therefore, the information from Vietnam would have been incomplete if postal codes are to be considered.

Insights can be obtained by adjusting the resolution of the map. A closer look for example, by looking into individual countries would provide a more detailed look at the locations. Figure 4.7 shows a zoomed view with higher resolution. In this figure, we can see the data points location in a province level.

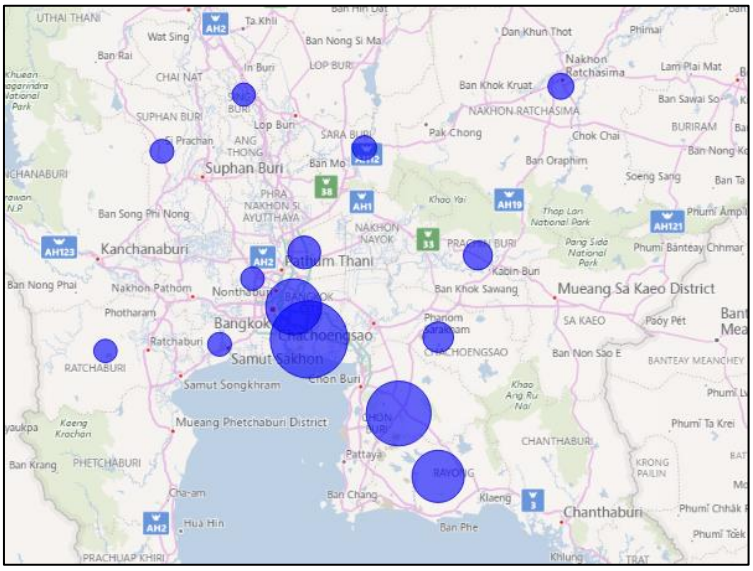


Figure 4.7 Supplier concentrations in Thailand, bubble type

The same visualization is used, but this time color saturation is used to depict frequency instead of bubble sizes.

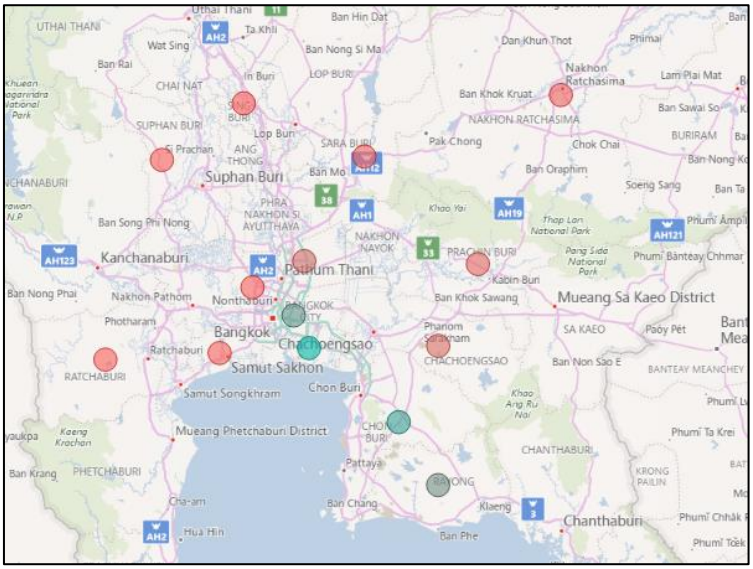


Figure 4.8 Supplier concentrations in Thailand, color saturation type

4.2.3 Radar Diagram

Radar charts, or sometimes called as Spider Chart, Web Chart, Polar Chart, or Star Plots, are used to compare multiple quantitative variables. This visualization makes it easy to see which variables have similar values or if there are outliers amongst each variable. Any dataset can be used and compared as long as the data must be quantitative.

Radar charts depicting the main product groups of all the suppliers in the data warehouse. In order to make this visualization, the following fields were considered: MNPROD and SUPP_NM.

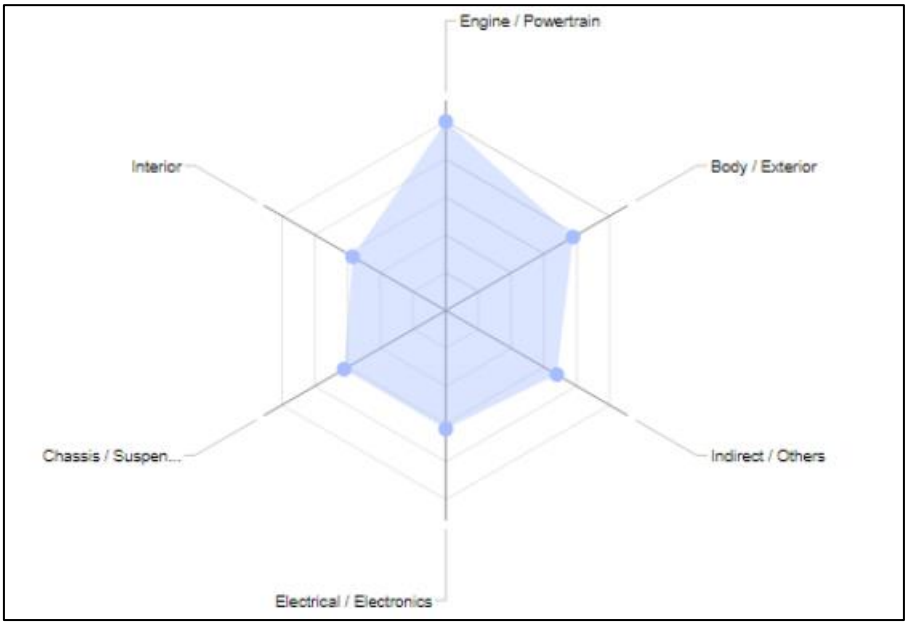


Figure 4.9 Radar chart

Figure 4.9 shows a radar chart of main product group produced by all the suppliers in the dataset. It shows that majority of the suppliers are involved with engine/powertrain products and components. As this dataset involves all automotive suppliers from southeast asia, the information that can be inferred from this chart implies that southeast asia has numerous suppliers involved in engine/powertrain compared to other product groups.

4.2.4 Tornado Diagram

Tornado diagrams, or sometimes known as Butterfly Charts, provide excellent visualization techniques for comparing two data sets side by side. It is ease to see how one series compare to the other series for a given data input in one look.

We needed a visualization to show us the relationship between each country's supplier base and the global suppliers. The supplier base may be grouped by separate countries and the global suppliers separated from the local suppliers.

This visualization uses TORNADO 1.3.0 and used attribute data COUNTRYRA and TOP100 were used. Figure 4.10 shows the result of the visualization.

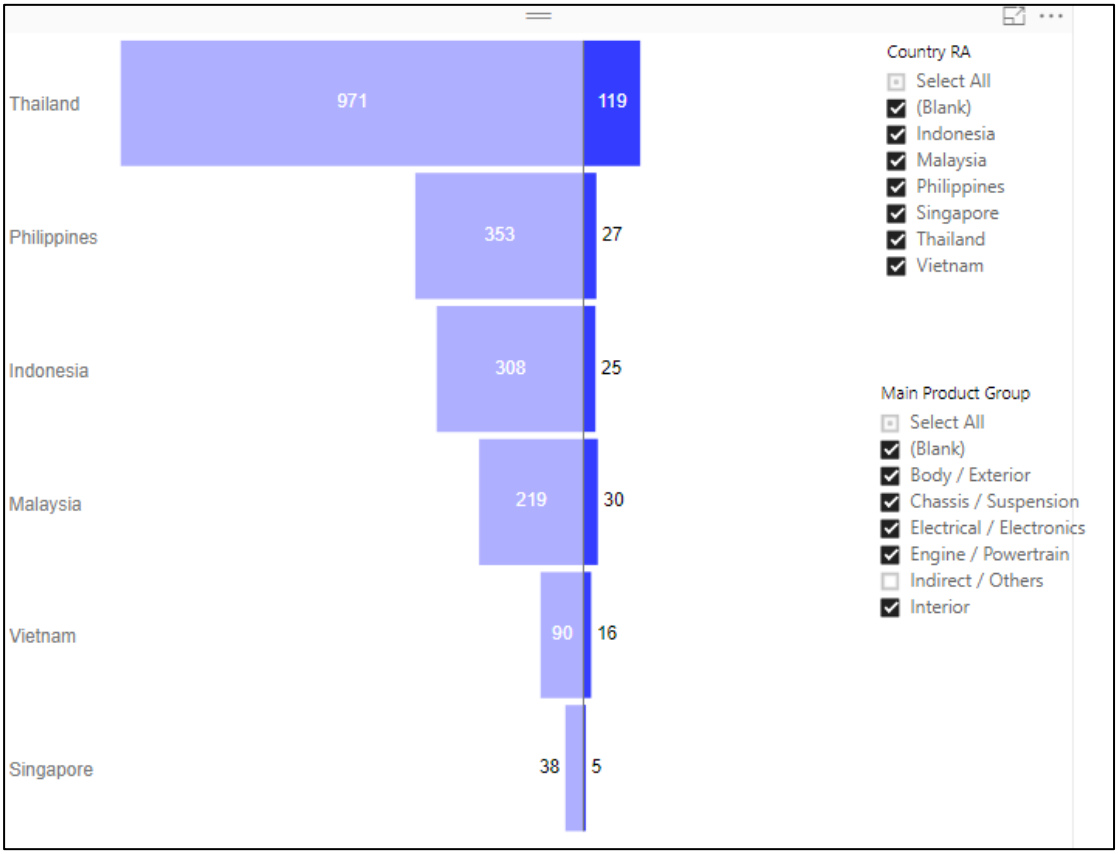


Figure 4.10 Tornado Diagram

4.2.5 Chord Diagram

Figure 4.11 shows an example of visualization CHORD. This visualization is a graphical method of displaying the inter-relationship between data in a matrix. The connections between entities are used to display that they share something in common. Chord diagrams are ideal for comparing the similarities within a dataset or between different groups of data.

In the figure shown above, data from supplier main product groups are compared to data depicting the sub product groups. In order to make this visualization, the following fields were used in the graphics: MNPROD, SBPROD, and SUPP_NM.

There are many possible uses for this graphical visualization since we can use the graphics to show relationship between two datasets. In this particular case, we tried to compare the relationship between main product group and sub product group. We wanted to know how the various automotive product groups relate to supplier manufacturing processes. Applying the filters and looking specifically at two countries – Philippines and Vietnam, we can see that the Electrical/Electronic products produced in these two countries are mainly using the manufacturing process – Assembly. There are also a few suppliers doing other activities such as plastic injection, casting and software development, which supports the Electrical/ Electronics industry in both countries.

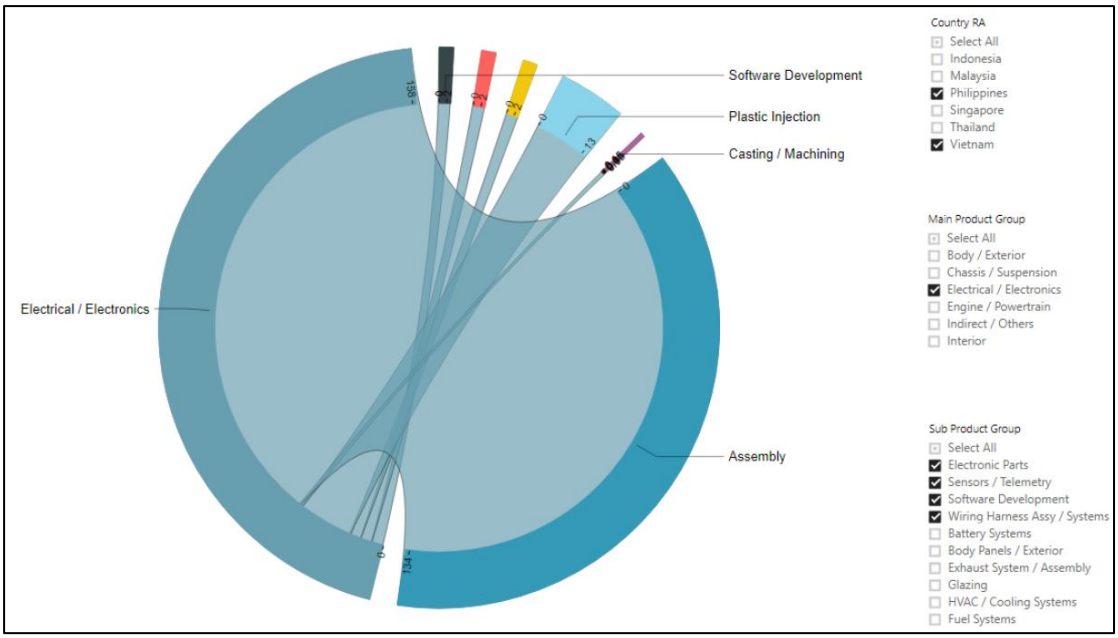


Figure 4.11 Chord Diagram

Further examples can be illustrated by the following diagrams in Figure 4.12 and Figure 4.13 Figure 4.12 shows the chord diagram looking into the relationships between suppliers involved in the Body/Exterior parts of the vehicle and the different manufacturing processes involved. Some interesting information that can be derived from the visualization graphic is that the main manufacturing process involved to make body parts are sheet metalforming and plastic injection processes.

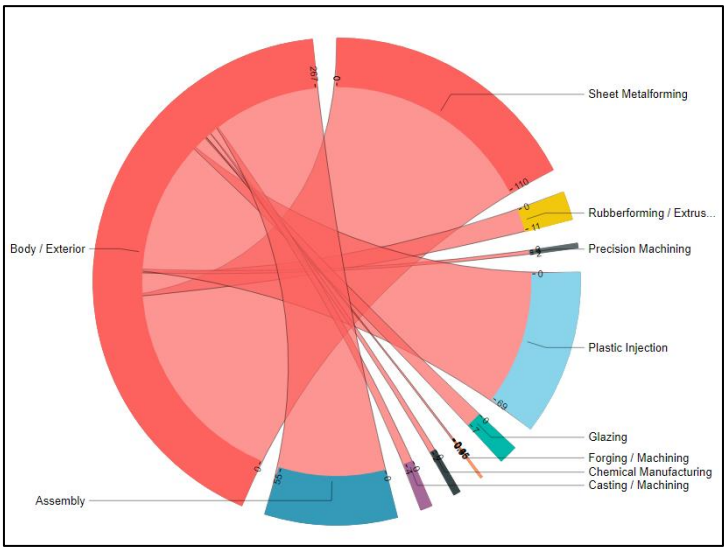


Figure 4.12 Chord Diagram

Another main component of the automotive vehicles are the products comprising group of chassis and suspension parts. Figure 4.13 shows that visualization when the filter is applied and only parts involved with Chassis/Suspensions are highlighted. The chord diagram showed the different processes involved with chassis/suspension parts and this time, the assembly process is shown to be the main manufacturing process involved in the manufacturing of chassis parts.

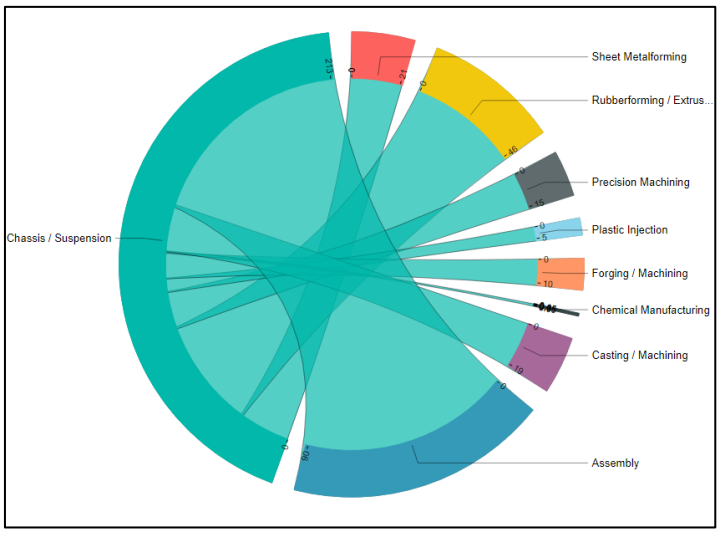


Figure 4.13 Chord Diagram

4.2.6 Tree Map Diagram

TREEMAP displays feature hierarchical data as a set of nested rectangles. Each branch is represented by a quadrangle, which is tiled with other smaller quadrangles. The dimension of the leaf is proportional to the specified dimension of the data. An advantage of treemaps is that they are able to show patterns for numerous items in a single chart, since by its nature, it uses space efficiently.

In this case, we needed to get a general overview of the nationality of owners and management in automotive companies in Southeast Asia. In order to make the visualization in Figure 4.14, the following fields were used in the graphics: NATIONAL and SUPP_NM.

We can see from the diagram that a huge majority of the owners/ management of automotive companies, comprise by the Japanese. This is an interesting insight since we can also observe that the automotive markets in the southeast Asian countries are dominated by the Japanese brands. The Japanese sell their brands to the SEA countries, and they also make the parts for these vehicles in these same countries. Thereby, having strong influence and impact on the supply and demand situation for these countries.

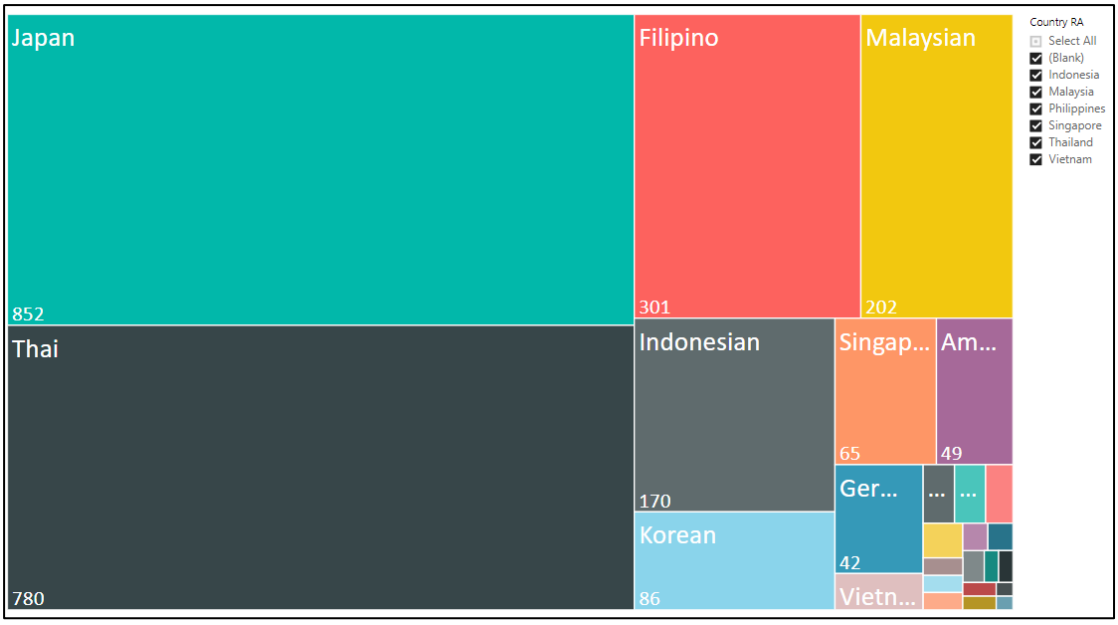


Figure 4.14 Treemap of company nationalities (ALL Southeast Asia)

Another example of the treemap is shown on the figure below. This time attribute data used in COUNTRYRA and MNMATL, and used as input to the visualization.

As expected, the main materials used in the automotive are Metals, followed by Plastic and Electronics. It would be interesting to note how this will now change given the architecture and technologies in an Electric Vehicles are much different from current automobile design.

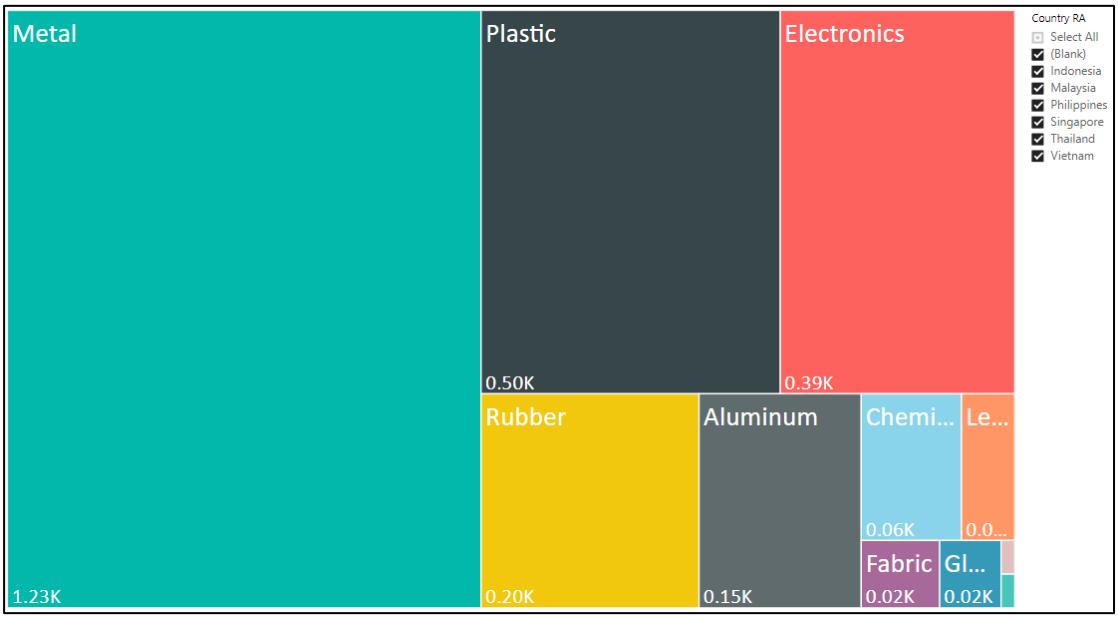


Figure 4.15 Treemap for ASEAN technologies

4.2.7 Dashboards

Aside from individual charts or diagrams, visualization software also provide powerful insights and ideas when individual charts are placed side by side to each other at the same time. These special visualizations, which are arranged based on a collection of resources and diagrams which are assembled together to create a single unified visual display, and is usually referred to as dashboards.

Figure 4.16 shows a typical dashboard, featuring four individual charts – Bar Chart, Radar Chart, Aster Chart and a Doughnut Charts. These are four individual diagrams giving information on four topics. When brought together though, they provide a clear view of a situation in a glance. It may show in a flash how the situation in unfolding or where may be a good place to look for certain technologies and its trends.

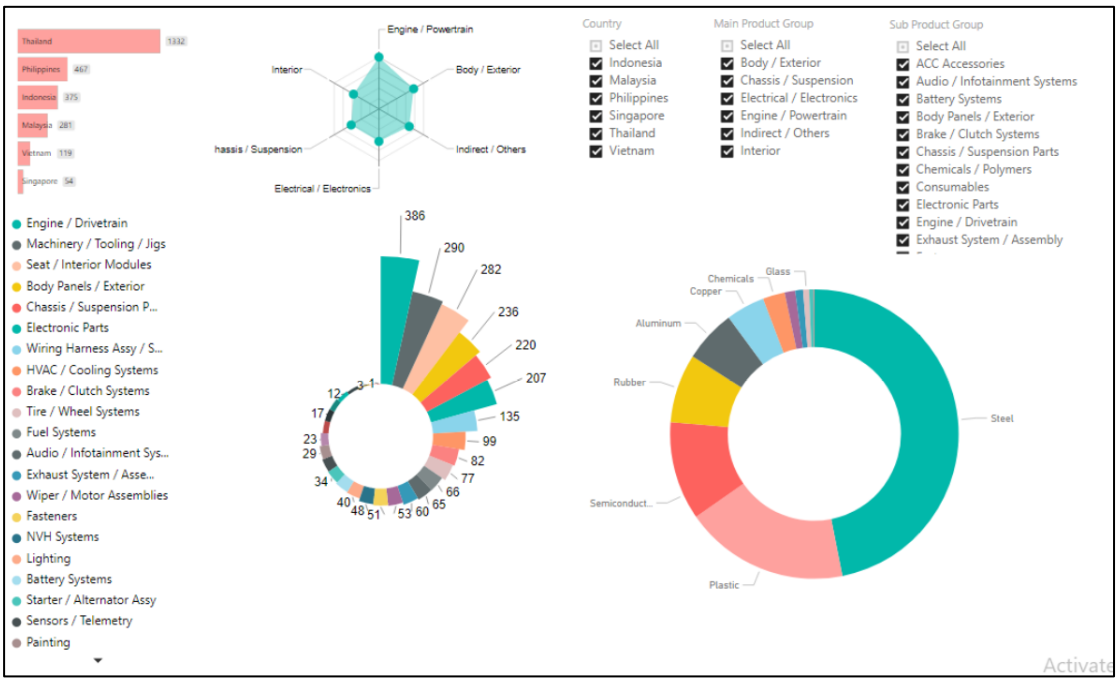


Figure 4.16 Dashboard featuring various charts.

4.3 Verification of the Study

Industry experts were consulted and interviewed. In this context, experts are considered to be employed or connected with the automotive industry for at least 10 years. Purchasing professionals were targeted in order to get a more focused view of the subject.

The interviewees were shown the visualization and were asked for their views and comments. Open-ended questions were asked in order to gather as much insight and knowledge from the diagrams.

Some comments were:

"The visualization software gave a concise specific view – grouping the data into countries, technologies, processes, etc.. It gives very clear picture of what is available in the market regarding auto parts supply."

"The tree map diagram on the different ownership structure – especially separating the Japanese, Europeans and the local Thai, Malay or Southeast Asians provides lots of information. It already provides us a picture of the type of technology, standards, way of working, types of product and quality level we can expect in the region."

"We can already get an idea which supplier will be impacted by technology disruptions, for example, exhaust system suppliers, or fuel tank suppliers. It will be interesting to know if the supplier can adapt quickly enough to the changing times or will just be like Kodak or Blackberry."

Above are some of the relevant comments obtained from the interview.

CHAPTER 5

5.1 Summary of Findings

This study has the main objective of making an overview of the automotive supply chain in Southeast Asia, develop a databank of relevant information, and then make a probable supplier network scenario for high voltage battery systems.

This study has successfully fulfilled the first two mentioned objectives, and has laid the foundations for the supplier network scenario.

Extensive desk research has revealed that there are currently no existing comprehensive supplier database for the automotive industry in Southeast Asia. There are country databases for the SEA mature countries like Thailand, Malaysia while the rest are still missing their databases. Vietnam has a large boom in investments in the automotive sector but had no updated national directory of the suppliers. Philippines also did not have a ready list, since that country was concentrating more on the electronics sector.

During the course of this study, different government agencies were consulted, internet desk studies and numerous interviews were done to gather, extract and centralize the location of the data into a database. As the data and information were in various formats, and in the case of the Philippines, was even in hardcopy format, some time and effort was expended to centralize, clean, normalize the data so it can be used for further processing.

Once the database reached a certain level of "cleanness" and groupings can be done, the data is imported onto a visualization software or Knowledge discovery. The visualization software provided a good overview of the automotive supplier industry in Southeast Asia – from the vehicle OEMs and down to Tier-level suppliers.

Regarding the objective to develop a supplier strategy in Southeast Asia, the study has found that the level of technology for the suppliers are still very low and unable to cope up with the technological level required to make automotive high voltage battery in Southeast Asia. However, there are some suppliers who are subsidiaries of global companies and can eventually setup some

production setup in the Southeast Asia region. However, these suppliers are just a handful and cannot support a ‘true’ supply chain.

Therefore, as an overview conclusion, the study has made it clear and simple that the supply base network for high voltage battery is still have a long way to be developed since the technological level of Southeast Asia suppliers are still not able to meet the technical requirements. And this has been made clear and evident from this study.

5.2 Areas for further study

Further analysis can be obtained by refining and adding more data and information into the database. Financial information can be added into the database, such as sales turnover, capitalization in order to identify suppliers that have adequate financial resources and can be approached to develop long term strategy. Organizational and functional capabilities can also be added onto the database, like identifying which suppliers have design and development capabilities or testing facilities, which can be approached in the future for technological colloborations.

Additionally, research can further go into what can be done with the data and use the data to find what is available in the internet, or social media such as Twitter. Sentiment analysis can performed to see which supplier are trending, or have presence and movement in cyberspace.

Another direction which the study could go would be to increase and expand the data warehouse. Gather more information about the different companies compiled in the database

BIBLIOGRAPHY

Arto, I., Andreoni, V., & Cantuche, J. (2015). Global impacts of the automotive supply chain disruption following the japanese earthquake of 2011. *Ecnomic Systems Research , 27* (3), 306-323.

Chae, B. (2015). Insights from hashtag #supplychain and Twitter analytics: considering Twitter and Twitter data for supply chain practice and research. *Int. J. Production Economics , 165*, 247-259.

Chae, K., & Olson, D. (2013). Business analytics or supply chain: a dynamic capabilities framework. *International Journal for Information Technology & Decision Making , 12* (1), 9-26.

Christofferson, A., & Karlsson, C. H. (2015). *Developing a framework* for *business analytics: a structure for turning data into actionable insights.* Chalmers University of Technology, Department of Technology Management and Economics. Gothenburg, Sweden: Chalmers University of Technology.

Chung, D., Elgqvist, E., & Santhanagopalan, S. (2016). *Automotive lithium-ion battery supply chain and US competitiveness considerations.* Joint Institute for Strategic Energy Analysis, Clean Energy Manufacturing Analysis Center. Colorado, USA: CEMAC.

Cooper, A., & Schefter, K. (2017). *Plug-in electric vehicle sales forecast through 2025 and the charging infrastructure required.* Institute for Electric Innovation. Washington DC: The Edison Foundation Institute for Electric Innovation.

Dremel, C., Herterich, C., Wulf, J., & Brenner, W. (2018). How Audi AG established big data alaytics in its digital transformation. *MIS Quarterly Executive , 16* (2), 81-100.

Feki, M., Boughzala, I., & Wamba, S. F. (2016). Big data analytics-enabled supply chain transformation: a literature review. *49th Hawaii International Conference on System Sciences* , 1123-1132.

Gunasekaran, A., Papadopoulus, T., Dubey, R., Wamba, S., Childe, S., Hazen, B., et al. (2016). Big data and predictive analytics for supply chain and organizational performance. *Journal of Business Research , 70*, 308-317.

Heaney, B. (2015). *The evolution of the supply chain - spotlight on the automotive industry.* Boston MA: Aberdeen Group.

Holsapple, C., Lee-Post, A., & Pakath, R. (2014). A unified foundation for business analytics. *Decision Support Systems* (64), 130-141.

IBM. (2010). *The smarter supply chain of the future.* IBM Institute for Busines Value. New York, USA: IBM Global Business Service.

IEA International Energy Agency. (2016). *Energy Technology Perspectives 2016: Towards Sustainable Urban Energy Systems.* Organisation for Economic Cooperation and Development. Paris: International Energy Agency.

Keim, D., & Kriegel, H. (1996). Visualization techniques for mining large databases: a comparison. *IEEE Transactions of Knowledge and Data Engineering , 8* (6), 9230938.

Marr, B. (2017, July 20). *The 7 best Data Visualization Tools Available Today*. Retrieved June 12, 2018, from www.forbes.com: https://www.forbes.com/sites/bernardmarr/2017/07/20/the-7-best-data-visualization-tools-in-2017/#441ca40a6c30

Mrak, M. (2000). *Globalization: trends, challenges and opportunities for countries in transition.* New York: United Nations Industrial Development Organization.

Mushtaq, N.-U.-S., & Sarwar, J. (2011). *A look into the future of the global automobile industry with an emphasis on emerging fuel technologies - rivalry strategy impact.* Copenhagen Business School, Department of International Economics and Management. Copenhagen: Copenhagen Business School.

Randomski, D. (2013, November 18). Supply chain dynamics and growth opportunities in advanced batteries. *The 27th International Electric Vehicle Symposium & Exhibition* , 45. Barcelona, Catalan, Spain: NEXTEnergy.

Rist, O. (2016, August 29). *10 Free Visualization Tools*. Retrieved June 12, 2018, from www.pcmag.com: https://www.pcmag.com/article/347315/10-free-data-visualization-tools

Rodriguez, M., & Paredes, F. (2015). Technological landscape and collaborations in hybrid vehicles industry. *Foresight-Russia , 9* (2), 6-21.

US Department of Energy. (2017). *Cost and price metrics for automotive lithium-ion batteries.* US Department of Energy, Office of Strategic Programs. US Department of Energy.

Valentine-Urbschat, M., & Bernhart, W. (2010). *Powertrain 2020 - the future drives electric.* Roland Berger Stategy Consultants.

Waller, M., & Fawcett, S. (2013). Data science, predictive analysis, and big data: a revolution that will transform supply chain design and management. *Journal of Business Logistics , 34* (2), 77-84.

Wang, G., Gunasekaran, A., Ngai, E., & Papadopoulus, T. (2015). Big data analytics in logistics and supply management: certain investigations for research and applications. *International Journal of Production Economics , 176*, 98-110.

Wirth, R., & Hipp, J. (2000). CRISP DM: Towards a standard process model for data mining. *roceedings of the 4th International Conference on the Practical Applications of Knowledge Discovery and Data Mining.*

ABOUT THE AUTHOR

Firstname, Surname	Kittiyakorn Khounarj
Birthdate	13 / 08 / 1972
Address	151/278 Moo 7 Surasak, Sriracha, Chonburi 20110
Education	Bachelor of Science in Chemical Engineering
	Chulalongkorn University
Work Experience	Michelin Siam Co., Ltd.
	General Motors (Thailand) Co., Ltd.
	Autoliv Asia ROH Co., Ltd.
	Momentive Performance Materials Co.,, Ltd.
	Lear Corporation Co., Ltd.
Current employment	Valeo Automotive Thailand Co., Ltd.