International Journal of Applied Operational Research
Vol. 5, No. 4, pp. 17-37, Autumn 2015

Journal homepage: ijorlu.liau.ac.ir

Technology Roadmap Prioritization in Acquisition Layer with Ranking Options of Market Layer: A Case Study

K. Fartash, M. A. Beheshtinia, B. Kargar Shahamat*

Received: 22 February 2015 **Accepted:** 11 July 2015

Abstract Roadmap is a strategic plan that describes the steps an organization needs to take to achieve stated outcomes and goals in different layers and these layers are closely related to each other. Lower layer is more important in planning processes. Acquisition layer is one of the most crucial layers in road mapping process. Today there are some international organizations that do policy making and depict technology roadmap in different areas. Manufacturing firms always had the limitation of utilizing these roadmaps. In this paper we examined electric and plug-in hybrid electric vehicles technology roadmap of international energy agency. Batteries as a hurdle in acquisition layer and electric cars of 2011 was ranked and prioritized from difference perspective, which can be used in technological development activities as guidance.

Keywords: Technology roadmap, Road mapping, Acquisition layer, Prioritization, Ranking.

1 Introduction

Today, there is no certainty and in order to cope this uncertainty, firms must have a robust plan for their future and this plans are required to be a live process. One the most effective tools that help planning for future and minimizing risks is roadmap. A roadmap is a plan that describes the steps an organization needs to take to achieve desire outcomes and goals. Roadmap outlines links among tasks and priorities for actions in near, medium and long term [1]. There are many kinds of roadmaps (such as science, technology, science & technology). Technology roadmap is the one, which emphasis on technology. As it said, roadmap is a tool to achieve goals and technology roadmaps are about to help attaining technological goals. In the world, there are some national or international organizations, that their duty is policy making. They monitor technological and climate changes and their decision are to prevent undesirable environmental events. Output of such processes is a report and usually there is a

* **Corresponding Author.** (✉)
E-mail: b.k.shahamat@gmail.com (B. Kargar Shahamat)

K. Fartash
Ph.D Candidate of Management of Technology, Faculty of Management and Accounting, Allameh Tabataba'i University, Tehran, Iran

M. A. Beheshtinia
Assistant Professor, Department of Industrial Engineering, Semnan University, Semnan, Iran

B. Kargar Shahamat
Ph.D Candidate of Management of Technology, Faculty of Management and Accounting, Allameh Tabataba'i University, Tehran, Iran

roadmap with it. In this kind of roadmaps, there are lots of actions must be taken; small firms can't put in practice all plans of roadmap. They must have a list of priorities to go through. In this paper, we want to examine one of international energy agency roadmaps and define its priorities that can be useful for manufacturing firms according to their capabilities. Electric and plug-in hybrid electric vehicle technology roadmap is the case of this paper.

This paper follows two significant goals. First goal is to explore purposes of roadmap in acquisition layer and define the most important challenges in acquisition layer and we do prioritization. Second goal is ranking six significant electric and plug-in hybrid electric vehicles, which sold in 2011.

There are lots organized attempts to develop technology roadmap literature including its approaches and applications. Almost all the previous researches, concentrate on depicting roadmaps not utilizing existing roadmaps according to their priorities. In this paper, we are going to cover this lack of literature and method of this research is as a guidance framework for future researches.

2 Review of literature

Technology roadmap is a flexible technique that is widely used within industry to support strategic and long-range planning [2] and currently is applied to several technological development plans, both in company and industry level organizations [3]. Technology road mapping is a structured mean for exploring and communicating the relationship between evolving and developing markets and between product and technologies over time [4]. Roadmap definition from Robert Galvin, advocate of science and technology is an extended look at the future of a chosen field of inquiry composed from the collective knowledge and imagination of the brightest drivers of change in that filed [5]. Roadmaps can take various forms, ranging between technology push and market pull. The most familiar approach is EIRMA approach [6]. This approach is shown fig. 1. In EIRMA approach, roadmap is a time-based chart, comprising a number of layers that include industrial and business perspectives [2].

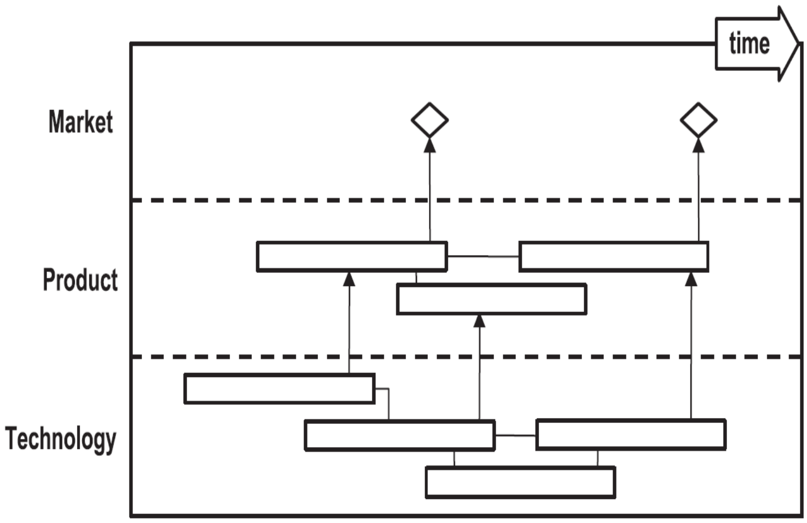


Fig. 1 Generic schematic of technology roadmap [6]

As it shown in fig.1, technology roadmap has three main layers that are closely related to each other. In a bit more detailed structure, each of above layers divides to some sub layers. Technology layer comprised of resources, technology acquisition and technology of products.

In this paper, our focus is on technology layer and we propose a method for defining technology acquisition priorities.

The beginning of TRM approaches was by U.S automotive industry and then systematic developing of TRM approaches was continued by Motorola and Corning [7] and then Lucent technology [8] was one of the significant pioneers of technology road mapping. Eight popular approaches of technology road mapping are Rockwell Automation approach [9], Kapple approach [10], fast start road mapping (t-plan) by Cambridge university as the most popular and used in practice [2], Sandia national lab approach [11], Royal mail approach in service firms [12] and scenario road mapping [13] are the most applied approaches of technology road mapping and each of them has some innovative steps. In none the above approaches, there is no sign of prioritizing action plans. All the approaches since the beginning of road mapping are to depicting and developing roadmaps. Focus of this paper is on utilizing existing roadmap with considering firm's capabilities.

In next sections of paper, we're going to examine electric and plug-in hybrid electric vehicle technology roadmap to define its priorities and ranking of electric cars of 2011.

2 Methodology

There are several ways of prioritizing with MADM methods. We chose two methods, Topsis and Promethee. For defining weights of attributes we used Shannon algorithm.

2.1 Shanon algorithm (entropy)

It is used to dividing 100% of weights to attributes. It has three steps and we calculate weights of attributes. In information theory, entropy is a measure of the uncertainty associated with a random variable [14]. In this context, the term usually refers to the Shannon entropy, which quantifies the expected value of attribute probability [15] The concept was introduced by Claude E. Shannon in his 1948 paper "A Mathematical Theory of Communication" [16]. Steps of Shannon algorithm is according below:

Step one:

$$E_j = -K\sum_{i=1}^{m}\left[P_{ij} Ln(P_{ij})\right], j = 1,2,3,\ldots,n$$

$$P_{ij} = \frac{r_{ij}}{\sum_{i=1}^{m} r_{ij}}, K = \frac{1}{Ln(m)}$$

Step two:

$$d_j = 1 - E_j$$

Step three:

$$w_j = \frac{d_j}{\sum d_j} \text{ (W}_\text{j} = \text{attribute weight's)}$$

2.2 Topsis

The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is a Multi Criteria Decision Analysis method, which was originally developed by Hwang and Yoon in 1981 [34] with further developments by Yoon in 1987 [17], and Hwang, Lai and Liu in 1993 [18]. TOPSIS is based on the concept that the chosen alternative should have the shortest geometric distance from the positive ideal solution and the longest geometric distance from the negative ideal solution. It is a method of compensatory aggregation that compares a set of alternatives by identifying weights for each criterion, normalizing scores for each criteria and calculating the geometric distance between each alternative and the ideal alternative, which is the best score in each criterion. An assumption of TOPSIS is that the criterion are monotonically increasing or decreasing. Normalization is usually required as the parameters or criteria are often of incongruous dimensions in multi-criteria problems [19, 20]. Compensatory methods such as TOPSIS, allow trade-offs between criteria, where a poor result in one criterion can be negated by a good result in another criterion. This provides a more realistic form of modeling than non-compensatory methods, which include or exclude alternative solutions based on hard cut offs [21].

2.3 Promethean

The Preference Ranking Organization Method for Enrichment of Evaluations and its descriptive complement Geometrical Analysis for Interactive Aid are better known as the PROMETHEE & GAIA methods [22, 23]. Based on mathematics and sociology, it was developed at the beginning of the 1980s and has been extensively studied and refined since then. It has particular application in decision making, and is used around the world in a wide variety of decision scenarios, in fields such as business, governmental institutions, transportation, healthcare and education [24]. Rather than pointing out out a "right" decision, the PROMETHEE & GAIA method helps decision makers find the alternative that best suits their goal and their understanding of the problem [25]. It provides a comprehensive and rational framework for structuring a decision problem, for identifying and quantifying its conflicts and synergies, clusters of actions and highlight the main alternatives and the structured reasoning behind.

Decision situations to which the PROMETHEE & GAIA can be applied include:

- Choice: The selection of one alternative from a given set of alternatives, usually where there are multiple decision criteria involved.
- Prioritization: Determining the relative merit of members of a set of alternatives, as opposed to selecting a single one or merely ranking them.
- Resource allocation: Allocating resources among a set of alternatives.
- Ranking: Putting a set of alternatives in order from most to least preferred.
- Conflict resolution: Settling disputes between parties with apparently incompatible objectives.

The applications of PROMETHEE & GAIA to complex multi-criteria decision scenarios have numbered in the thousands, and have produced extensive results in problems involving planning, resource allocation, priority setting, and selection among alternatives [26]. Other areas have included forecasting, talent selection, and tender analysis.

2.3.1 PROMETHEE Rankings

PROMETHEE I: PROMETHEE I is a partial ranking of the actions. It is based on the positive and negative flows. It includes preferences, indifferences and incomparability’s (partial preorder).
PROMETHEE II: PROMETHEE II is a complete ranking of the actions. It is based on the multi criteria net flow. It includes preferences and indifferences (preorder).

3 Case Study

Our case is electric and plug in hybrid electric vehicles technology roadmap version of 2011. In this section, first we introduce international energy agency and then we describe EV/PHEV technology roadmap. Finally prioritize batteries and electric cars of 2011.

3.1 International Energy Agency

The IEA is made up of 28 member countries. The IEA was founded in response to the 1970s oil crisis in order to help countries co-ordinate a collective response to major disruptions in oil supply through the release of emergency oil stocks to the markets. The main objectives of the IEA were:

- to maintain and improve systems for coping with oil supply disruptions;
- to promote rational energy policies in a global context through co-operative relations with non-member countries, industry and international organizations;
- to operate a permanent information system on the international oil market;
- to improve the world’s energy supply and demand structure by developing alternative energy sources and increasing the efficiency of energy use;
- to promote international collaboration on energy technology; and
- to assist in the integration of environmental and energy policies.

Today, the IEA’s four main areas of focus are:

- **Energy security**: Promoting diversity, efficiency and flexibility within all energy sectors;
- **Economic development**: Ensuring the stable supply of energy to IEA member countries and promoting free markets to foster economic growth and eliminate energy poverty;
- **Environmental awareness**: Enhancing international knowledge of options for tackling climate change; and
- **Engagement worldwide**: Working closely with non-member countries, especially major producers and consumers, to find solutions to shared energy and environmental concerns.

3.2 Electric and plug-in hybrid electric vehicles Technology roadmap

This technology roadmap has been updated in June 2011 [27] and we used last version for our research. This roadmap for the first time identifies a detailed scenario for the evolution of these types of vehicles and their market penetration, from annual production of a few thousand to over 100 million vehicles by 2050. It finds that the next decade is a key “make or break” period for EVs and PHEVs: governments, the automobile industry, electric utilities and other stakeholders must work together to roll out vehicles and infrastructure in a coordinated fashion, and ensure that the rapidly growing consumer market is ready to purchase them. The roadmap concludes with a set of near-term actions that stakeholders will need to take to achieve the roadmap’s vision. This roadmap provides additional focus and urgency to the international discussions about the importance of electric-drive vehicles as a technology solution. This roadmap has been updated through June 2011 to reflect recent developments with electric and plug-in hybrid vehicles.

3.2.1 Roadmap scope

The Electric and Plug-in Hybrid Vehicles Roadmap has been developed in collaboration with governments, industry and non-government organizations. The approach began with a review and assessment of existing domestic and international collaboration efforts by member governments and industry groups on EV/PHEV technology and deployment. These efforts included all technical and policy-related activities associated with moving this technology from the laboratory to widespread commercial use. This roadmap covers the two main types of electrification for light-duty vehicles: pure battery electric vehicles (EVs) and plug-in hybrid electric vehicles (PHEVs).

3.2.2 Roadmap vision

Achieve the widespread adoption and use of EVs and PHEVs worldwide by 2050 and, if possible, well before, in order to provide significant reductions in greenhouse gases (GHG) emissions and oil use. In the near term, electric-drive vehicles will most likely appear as personal vehicles—sedans, light trucks and electric scooters and bikes.

3.2.3 Roadmap purpose and content

The penetration rate of pure battery EVs and PHEVs will be influenced by a range of factors: supplier technologies and vehicle offerings, vehicle characteristics, charging infrastructure, and, as a function of these, consumer demand. Government policies influence all of these factors. The primary role of this roadmap is to help establish a “big picture” vision for the EV/PHEV industry; set approximate, feasible goals and milestones; and identify the steps to achieve them. This roadmap also outlines the role for different stakeholders and describes how they can work together to reach common objectives.

3.3 Current status of EV/PHEV

Battery-powered EVs use an electric motor for propulsion with batteries for electricity storage. The energy in the batteries provides all motive and auxiliary power onboard the vehicle. Batteries are recharged from grid electricity and brake energy recuperation, and also potentially from non-grid sources, such as photovoltaic panels at recharging centers [27]. EVs offer zero vehicle emissions of GHGs and air pollutants, as well as very low noise. An important advantage of EVs over conventional ICE vehicles is the very high efficiency and relatively low cost of the electric motor. The main drawback is their reliance on batteries that presently have very low energy and power densities compared to liquid fuels. Although there are very few electric automobiles for road use being produced today, many manufacturers have announced plans to begin serious production within the next two to three years.

Hybrid electric vehicles (HEVs) use both an engine and motor, with sufficient battery capacity (typically 1 kWh to 2 kWh) to both store electricity generated by the engine or by brake energy recuperation. The batteries power the motor when needed, to provide auxiliary motive power to the engine or even allow the engine to be turned off, such as at low speeds.

None of today's hybrid vehicles has sufficient energy storage to warrant recharging from grid electricity, nor does the power train architecture allow the vehicles to cover the full performance range by electric driving.

PHEVs are a potentially important technology for reducing the fossil fuel consumption and CO_2 emissions from light duty vehicles (LDVs) because they can run on electricity for a certain distance after each recharge, depending on their battery's energy storage capacity expected to be typically between 20 km and 80 km.

3.3.1 Battery cost

Energy storage requirements create major difficulties for the success of EVs. For example, if drivers demand 500 km of range (about the minimum for today's vehicles), even with very efficient vehicles and battery systems that are capable of repeated deep discharges, the battery capacity will need to be at least 75 kWh. At expected near-term, high-volume battery prices of approximately USD 500/kWh, the battery alone would cost USD 35 000 to USD 40 000 per vehicle. Thus, to make EVs affordable in the near-term, most recently announced models have shorter driving ranges (50 km to 200 km) that require significantly lower battery capacities [27].

3.3.2 Recharging infrastructure

If charging components such as converters are located on board vehicles, many vehicles should be able to use standard outlets and home electrical systems, at least for slow recharging (such as overnight). For daytime recharging, public recharging infrastructure (for example at office locations, shopping centers and street parking) will be needed. Currently, public recharging infrastructure for EVs is very limited or non-existent in most cities, though a few cities have already installed significant infrastructure as part of pilot projects and other programs. To enable and encourage widespread consumer adoption and use of EVs, a system with enough public recharging locations to allow drivers to recharge on a regular basis during the day will be necessary. Such infrastructure will effectively increase the daily driving range of EVs (and PHEVs range on electricity). Public charging infrastructure could include opportunities for rapid recharging, either via fast recharge systems (with compatible batteries) or via battery swapping stations that allow quick replacement of discharged battery packs with charged ones.

3.4 Batteries: The key technology for EVs and PHEVs

3.4.1 Major technology challenges

Although serious technical difficulties remain that prevent the market introduction of EVs and PHEVs, battery technology is an integral part of these vehicles that still needs to be significantly improved. Both current and near-term battery technologies still have a number of issues that need to be addressed in order to improve overall vehicle cost and performance. These characteristic include:

Battery storage capacity: Batteries for EVs need to be designed to optimize their energy storage capacity, while batteries for PHEVs typically need to have higher power densities. However, economies of scale may ease the development of a single battery type, ultimately resulting in some compromises on other features

Battery duty (discharge) cycles: Batteries for PHEVs and EVs have different duty cycles. PHEV batteries are subject to deep discharge cycles (in all-electric mode), in addition to frequent shallow cycles for power assist and regenerative braking when the engine is in hybrid mode (similar to conventional ICE-HEVs). Batteries for EVs are more likely to be subjected to repeated deep discharge cycles without as many intermediate or shallow cycles.

Durability, life expectancy, and other issues: Batteries must improve in a number of other respects, including durability, life expectancy, energy density, power density, temperature sensitivity, reductions in recharge time, and reductions in cost. Battery durability and life expectancy are perhaps the biggest technical difficulties to commercial application in the near term.

3.5 Comparison of battery technologies

Fig. 2 shows a general comparison of the specific power and energy of a number of battery technologies. However, there is an inverse relationship between specific energy and specific power (i.e., an increase in specific energy correlates with a decrease in specific power), lithium ion batteries have a clear edge over other electrochemical approaches when optimized for both energy and power density [27]. So we decided to compare batteries of ion lithium family.

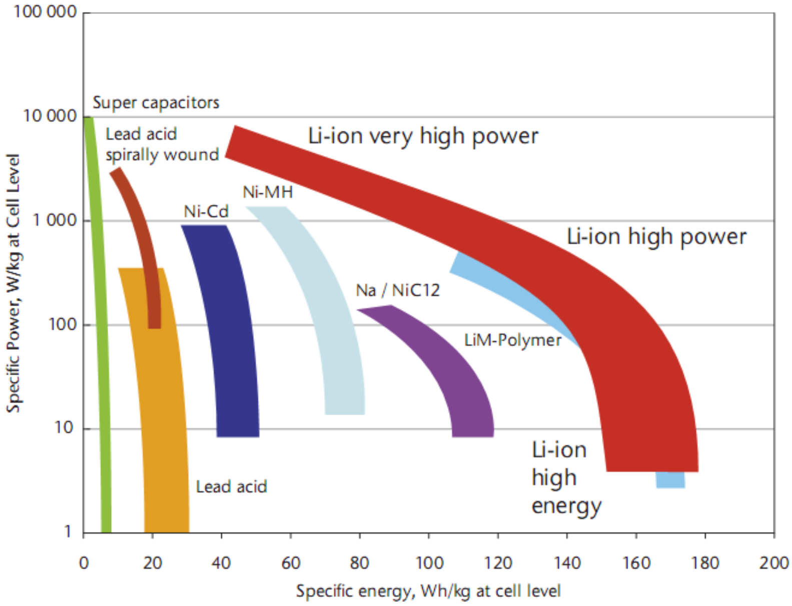


Fig.2 Specific energy and specific power of different battery types [27]

Within the lithium-ion family, there is a range of different types and configurations of batteries. These vary in terms of characteristics such as battery life, energy, power, and abuse tolerance. A summary of five battery chemistries and the strengths and weaknesses along these dimensions is shown in Table 1. Comparing and ranking of these batteries with six technical features will be done.

Table 1 Lithium-ion battery characteristics, by chemistry [28]

	Lithium cobalt oxide ($LiCoO_2$)	Nickel, cobalt and aluminum (NCA)	Nickel-manganese-cobalt(NMC)	Lithium polymer ($LiMn_2O_2$)	Lithium iron phosphate ($LiFePo_4$)
Energy	Good	Good	Good	Average	Poor
Power	Good	Good	Good	Good	Average
Low T	Good	Good	Good	Good	Average
Calendar life	Average	Very Good	Good	Poor	Very High
Cycle life	Average	Very Good	Good	Average	Average
Safety	Poor	Poor	Poor	Average	Good
Cost/kWh	Very High	High	High	High	High
Maturity	High	High	High	High	Low

In the near-term, the existing suite of lithium batteries, and a few other types, will be optimized and used in PHEVs and EVs. In the longer-term, new battery chemistries with significantly higher energy densities need to be developed to enable the development and use of PHEVs and EVs with a longer all-electric range. It is expected that new chemistries can outperform existing chemistries by incorporating high-capacity positive electrode materials, alloy electrodes, and electrolytes that are stable at five volts. Ultimately, new battery chemistries with increased energy density will facilitate important changes in battery design. Increased energy density means energy storage systems will require less active material, fewer cells, and less cell and module hardware. These improvements, in turn, will result in batteries, and by extension EVs/PHEVs, that are lighter, smaller and less expensive.

As it stated before, battery is major technology challenge and it is very important to decide which battery has the best features, in order to develop. Because of very expensive cost of battery technology, it will be very recourse consuming and false technology development will face with lots of difficulty besides the postponing of roadmap plan.

First data of table 1 we changed qualitative data to quantitative via nine point likert-scale, then with Shannon algorithm we computed weight of each criteria as table 2 by Shannon entropy method. We did use 9 nine point likert spectrum to transform data of table 1 from qualitative to quantitative data. Our likert spectrum for ideal positive is shown is fig.3 and ideal negative spectrum is exactly reverse of fig.3 spectrum.

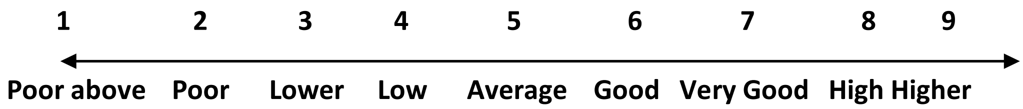


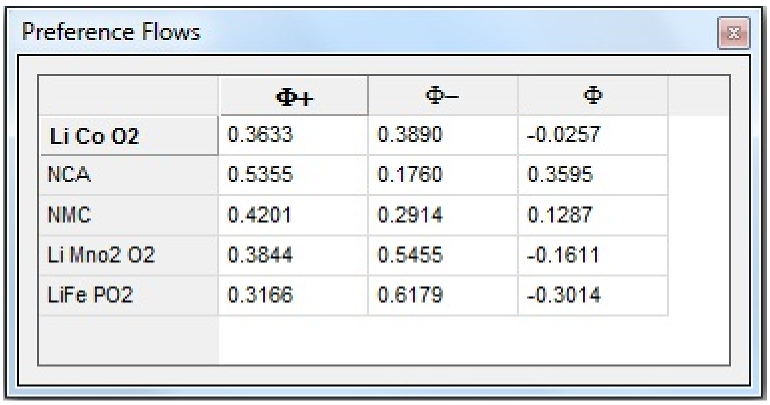
Fig.3 Nine point likert spectrum for transforming qualitative positive ideal data

Weights of each of 8 features of table 1 calculated and are shown in table 2.

Table 2 Weights of battery criteria (selected batteries of fig.2)

energy	power	lower t	calendar life	cycle life	safety	cost	maturity
0.134572	0.005727	0.005727	0.405555	0.022886	0.293933	0.0658	0.0658

Noted that because of very low weight and similarity of data, maturity and lower t were omitted from computation the most important reason of removing these two features was similarity of batteries in those features. After defining weight's, with and Promethean method, priority and ranking of each battery computed as below. Promethean result includes PROMETHEE I (partial ranking of the actions with preferences and indifferences threshold) and PROMETHEE II (complete ranking of the actions with preferences and indifferences threshold) and GAIA modeling (geometrical modeling that locates options with features and net flow). These results are shown in fig.4, fig.5 & fig.6.


Preference Flows

	Φ+	Φ−	Φ
Li Co O2	0.3633	0.3890	-0.0257
NCA	0.5355	0.1760	0.3595
NMC	0.4201	0.2914	0.1287
Li Mno2 O2	0.3844	0.5455	-0.1611
LiFe PO2	0.3166	0.6179	-0.3014

Fig.4 Positive, negative & net flow of batteries ranking

Then we did prioritization with PROMETHEE I and PROMETHEE II.

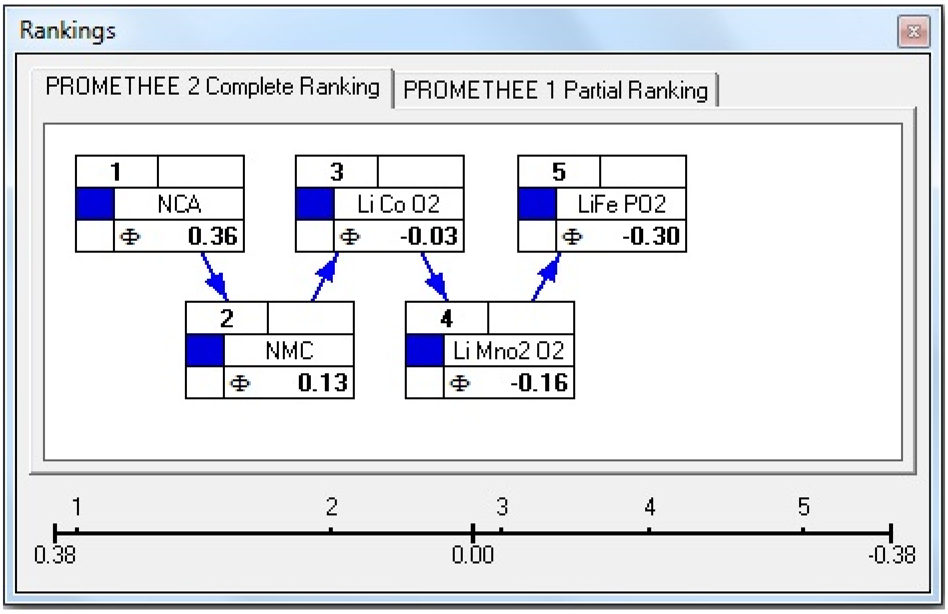


Fig.5 Complete ranking of batteries

In complete ranking ranking are calculated without considering preferences and indifferences threshold and priorities for R&D activities (for battery manufacturer) can be extracted from fig.5 and fig.6.

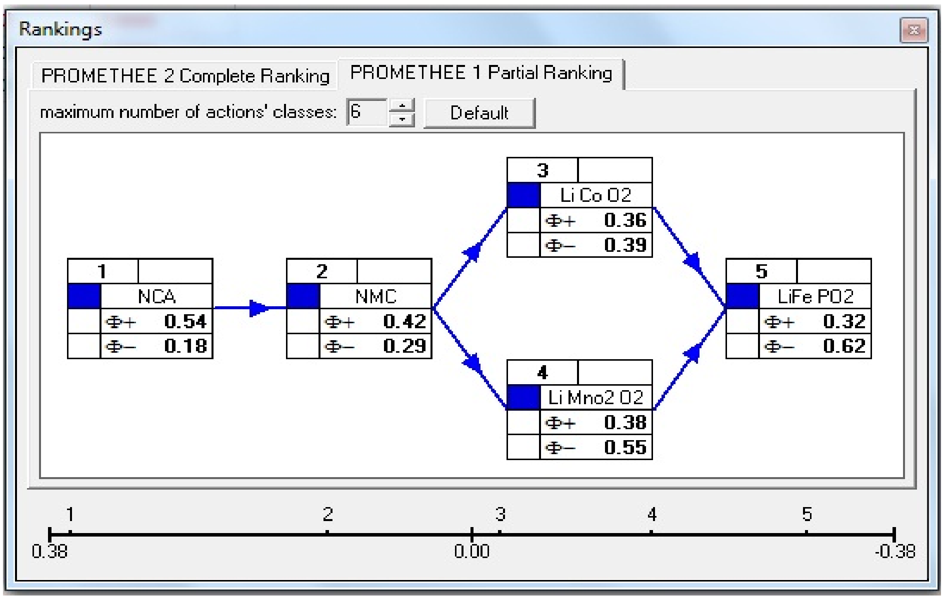


Fig.6 Partial ranking of batteries

In partial ranking according to fig.6 ranking is done with preference and difference considerations. Level function was used for all features except cost. V-shape function was used for cost. Preference and indifference threshold was 10% and 3% in respect. These functions are the same of car rankings. For cost, preference threshold is 5%. As it can be seen in fig.5 option 4 and 5 have no significant differences with each other according to our thresholds. In selecting option 4 and 5 we must act carefully and this is one of the beneficiaries of PROMETHEE. It must be stated that all features have positive ideality, except cost that has negative ideality. In fig.7 GAIA modeling of batteries is shown.

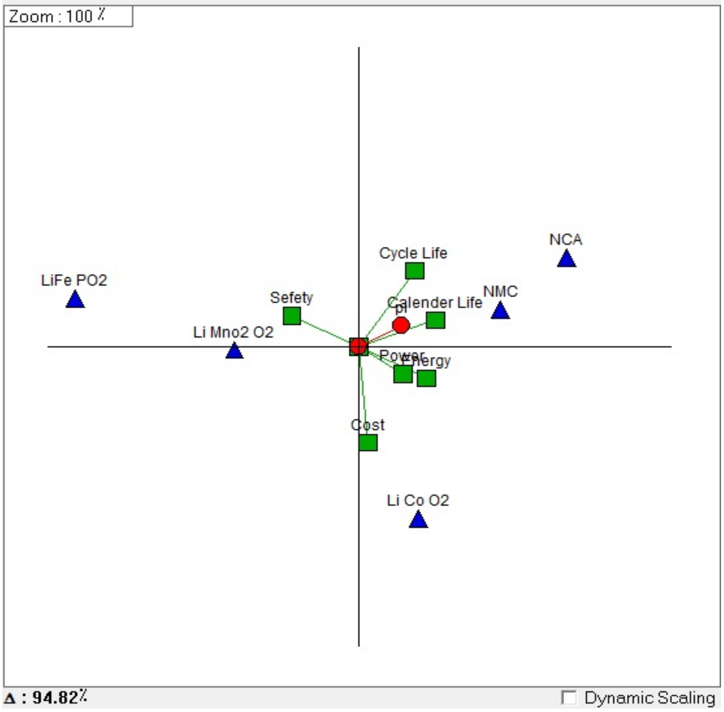


Fig.7 GAIA modeling of batteries

Red circle is net flow and options are shown with blue triangle and features are shown with green square. GAIA modeling show situation of each option and features and it is easy to decide with option we're going to invest, because all aspects of a decision is supported and easy to find with GAIA modeling. In appendix.1 GAIA modeling of options and features are shown.

For more assurance, we also did the ranking with TOPSIS method. TOPSIS is risk preventing method and this conservative ranking without any preference and indifference can be useful for managers to check their decision from risk management perspective.
Results of ranking with Topsis are shown in table 3.

Table 3 Battery ranking with TOPSIS method

Battery Rankings	cl_i	
$A_2(NCA)$	$cl_2=$	0.626
$A_3(NMC)$	$cl_3=$	0.575
$A_1(li\ Co\ O_2)$	$cl_1=$	0.503
$A_4(Li\ mno_2\ O_2)$	$cl_4=$	0.373
$A_5(Li\ Fe\ Po_2)$	$cl_5=$	0.372

Results of TOPSIS and PROMETHEE prioritization are the same. It shows that decision about R&D in batteries is clear and ranks with these two methods are the same. But it may not happen always, so we must expect the possibility of completely different result from them. In TOPSIS there is no partial ranking and can't differentiate options easily. It is also not clear that how much two options differ from each other.

3.6 Electric car ranking
3.6.1 Blue Map scenario

The Energy Technology Perspectives 2010 BLUE Map scenario sets an overall target of a 50% reduction in global energy-related CO_2 emissions by 2050 compared to 2005 levels. In the BLUE Map scenario, transport contributes to this overall reduction by cutting CO_2 emissions levels in 2050 to 30% below 2005 levels [29]. This reduction is achieved in part by accomplishing an annual sale of approximately 50 million light-duty EVs and 50 million PHEVs per year by 2050, which is more than half of all LDV sales in that year [30]. The EV/PHEV roadmap vision reflects the future EV/PHEV market targets set by the BLUE Map scenario. Global expected EV and PHEV sales in BLUE map scenario, during 2010–2050 is shown fig.8 and table 4.

Table 4 Global EV and PHEV sales in BLUE Map, 2010–2050(millions per year) [27]

	2010	2015	2020	2025	2030	2035	2040	2045	2050
EV	0	0.7	4.9	13.1	24.6	35.6	47.7	56.3	59.7
PHEV	0	0.3	2	1.5	8.7	13.9	23.2	33.9	46.6
Total	0	1.1	6.9	17.7	33.3	49.5	70.9	90.2	106.4

In fig.8 is also sales forecasted during 2010 to 2050 according to their type is shown.

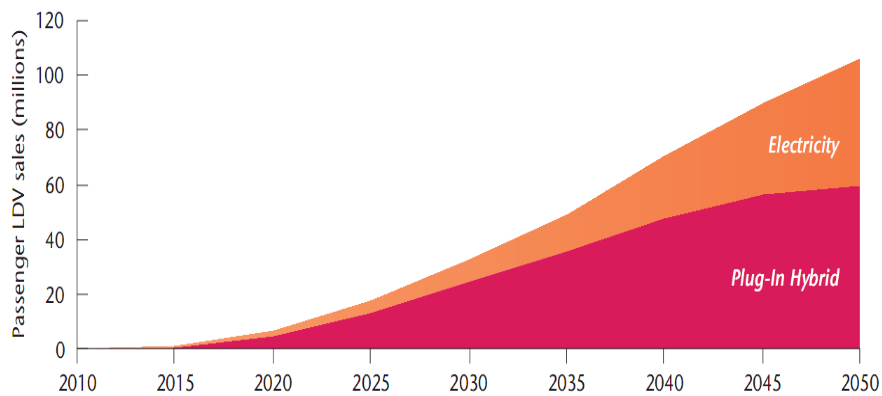


Fig.8 Annual global EV and PHEV sales in BLUE Map scenario [30]

There are two particularly important assumptions in the BLUE Map projections for EV/PHEV sales and resulting CO_2 reduction impacts:

- Vehicle model types and sales growth rates
- Vehicle efficiencies

Although the ramp-up in EV/PHEV sales is extremely ambitious, a review of recently announced targets by governments around the world suggests that these combined targets add up to a similar ramp-up through 2020. Additionally, most of these announcements considered were made in the past 12 months, demonstrating the high priority that developing and deploying EV/ PHEV technology has on an international level. National EV/PHEV slaes target in several countries of the world from now to 2020 is shown in fig.9.

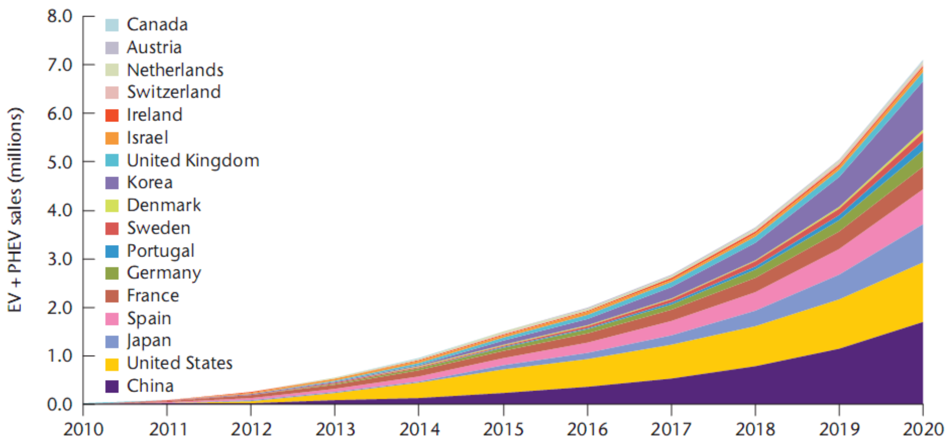


Fig.9 National EV/PHEV sales targets if national target year growth rates extend to 2020 (IEA transport energy, 2009)

3.6.2 The most significant component of EV/PHEV cars

There are a number of hurdles that must be overcome for EVs to succeed commercially and also technologically. Successful business models will need to be developed to overcome the following hurdles.

Battery cost

The up-front cost of batteries, that may be more than USD 10,000 per vehicle or more in the near-term, will be difficult to overcome unless these costs to the consumer can be spread over years. An advantage of amortizing battery costs is that these costs could, in theory, be bundled in with monthly payments for electricity, taking advantage of the relatively low cost of electricity compared to gasoline fuel. In the previous section of research, we prioritized ion-lithium batteries so manufacturer can easily decide which battery to develop.

Vehicle range

A car with a limited driving range (e.g., less than 200km) will need to have plenty of opportunities to recharge. Recharge stations will be needed at high-traffic locations such as train stations, shopping malls, and public parking areas. Rapid recharge or battery swapping systems may also be important, particularly on highways and expressways and along other routes where a quick recharge will be needed. So infrastructure plays a very important role in EV/PHEV cars introduction.

Driver information

Driver information is a key feature for any public infrastructure will be for drivers to easily locate stations. With the widespread use of GPS technology, this challenge is being addressed. EVs can be sold with GPS systems specially designed to show available recharging infrastructure even the available number of parking spaces at particular locations. This will reduce much of the uncertainty and stress that limited refueling infrastructure can have car owners [27].

Critical mass and economies of scale

Strategic planning, which focuses vehicles and infrastructure in certain areas can help attain operating densities and economies of scale, rather than attempt too wide a range of coverage at the start. First targeting fewer cities with more infrastructure and vehicles may be a more successful approach. Scale economies must also be sought in terms of total vehicle and battery production, once a plan is developed, it should be executed relatively as fast as possible. The faster that manufacturers can get to 50 000 or even 100 000 units of production (e.g., for a particular model of EV/PHEV), the faster costs will come down. The same holds true for batteries and for.

Specifications of several plug in vehicles sold or expected to be sold in 2011 is shown in table5. We did our ranking between six most famous and significant cars that expected to be sold or sold in 2011.

Table 5 Specifications of several plugs in vehicles sold or expected to be sold in 2011 [27]

OEM	Country	Model	Type	Battery capacity (kWh)	Mileage	Size(m) L * W * H			Weight (Kg)	Price (USD)
Nissan	Japan	Leaf	EV	24	160	4.44	1.77	1.54	1520	32800
Mitsubishi	Japan	iMiEV	EV	16	160	3.39	1.47	1.61	1172	30000
BYD	China	E6	EV	60	350	4.55	1.82	1.63	2020	35000
GM	US	Volt	PHEV	16	60	4.50	1.78	1.43	1715	41000
Tesla	US	Roadster	EV	56	394	3.94	1.85	1.12	1236	128500
Mahindra	India	NXG	EV	14	200	2.62	1.64	1.55	825	26388

Five technical features of EV/PHEV for ranking are battery capacity, mileage, size, weight and price. Ideality of weight and price is negative and three other features are ideality positive. With the help of Shannon algorithm (entropy) weights of each feature calculated and shown in table 6.

Table 6 Weights of EV/PHEV car features

Battery Capacity	mileage	size(L)	weight	price($)
0.31468	0.243798	0.022052	0.065645	0.353826

PROMETHI I and PROMETHE II ranking was done in order to define ranks and feature development priorities. Net flow of ranking (including positive and negative flow) is shown in fig.10. Net flow provides a full supervision on both negative and positive ranking. PROMETHI I and PROMETHE II ranking results are shown in fig.11 and fig.12. In PROMETHI I ranking was done with preference and indifference threshold of 10% and 3% in respect and cost preference threshold is 5%. All features preference except cost and indifference functions is level function and for cost (because of more sensitivity) V-shape function was used. In PROMETHEE II ranking was done without considering preferences and indifferences.

Preference Flows

	Φ+	Φ–	Φ
Nissan Leaf	0.4762	0.4707	0.0055
Mitsubishi	0.4470	0.4278	0.0192
BYD	0.6256	0.3444	0.2811
GM	0.1689	0.7682	-0.5993
Tesla	0.5437	0.4171	0.1266
Mahindra	0.5834	0.4166	0.1668

Fig.10 Positive, negative & net flow of EV/PHEV cars ranking

Net flow is subtraction of positive and negative flow ranking. BYD and Mahindra have the highest positive flow but their negative flow is also considerable and it shows that EV/PHEV cars have undeniable weak points that are somehow equal the strength of cars. These cars must improve a lot to satisfy customer needs. Car manufacturer may consider result of this ranking as mean to improve their products.

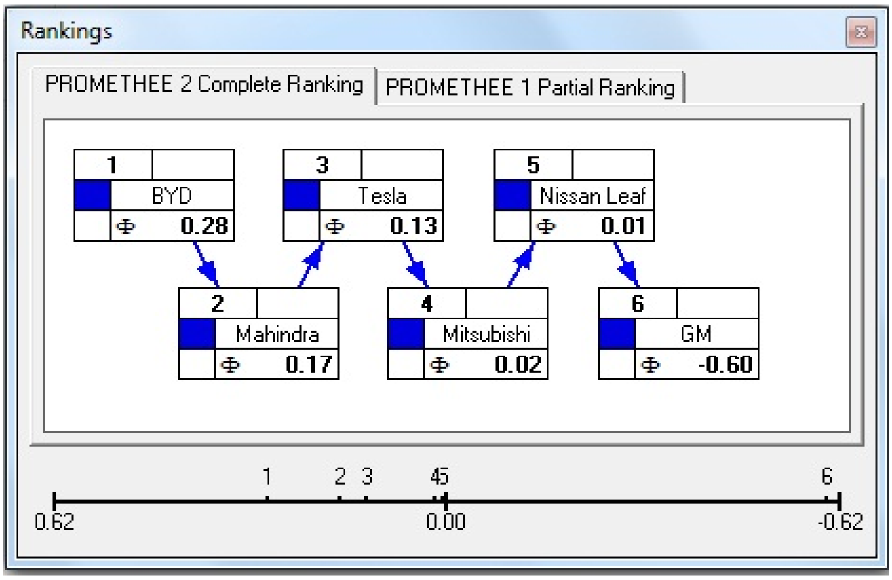


Fig.11 Complete ranking of EV/PHEV cars

Complete ranking shows the ranks of cars but it can't determine differences of options. In PROMETHEE I differences of cars by preference and indifference functions easily can be notified.

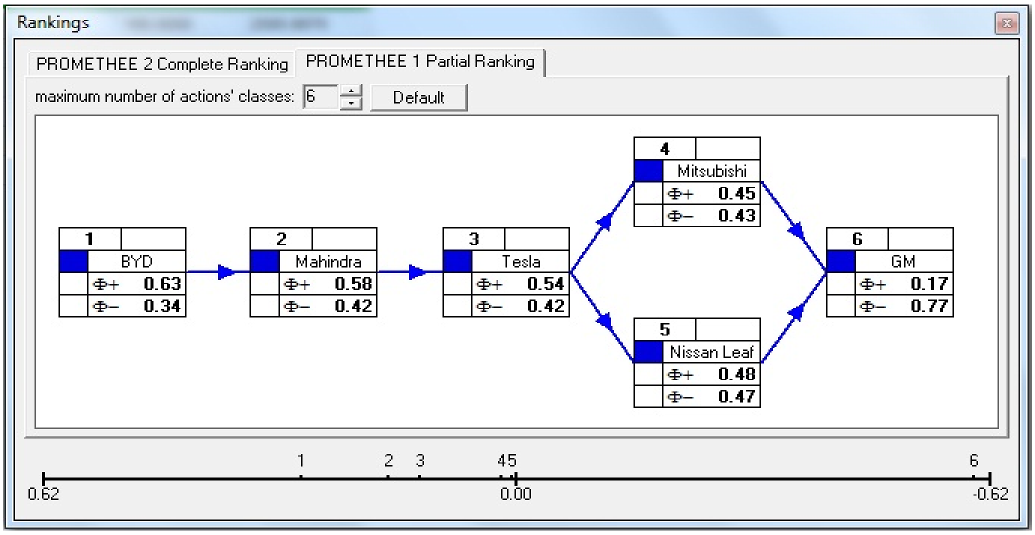


Fig.12 Partial ranking of EV/PHEV

GAIA modeling of EV/PHEV cars was done and situation of each feature and options and net flow is shown fig.13. GAIA modeling with locating features, options and net flow, situation of each option and their locations is one of benefits of PROMETHEE ranking.

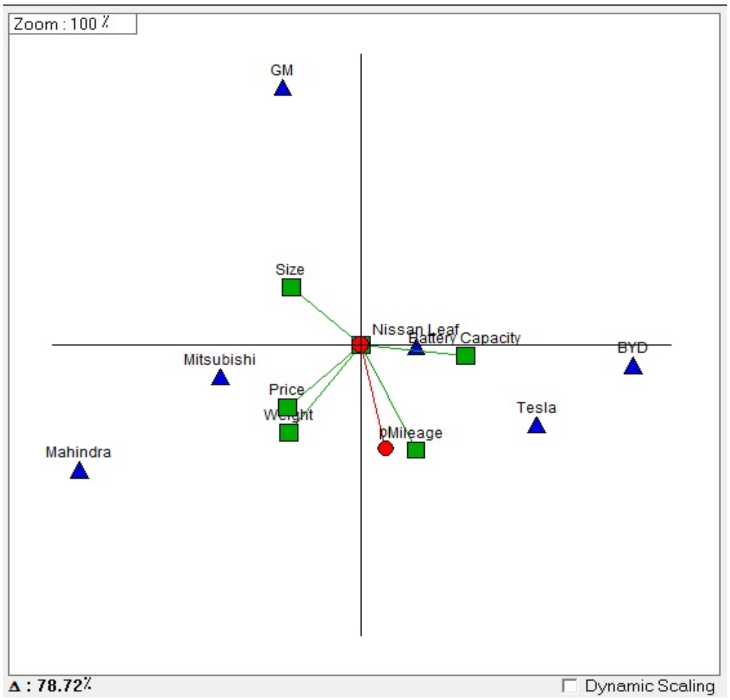


Fig.13 GAIA modeling of EV/PHEV cars

Additional ranking of GAIA modeling is in appendix 2. As it shown above features and options are displayed with green square and blue triangle in respect. Net flow is also illustrated with red circle. For double check on cars ranking we also did the ranking with TOPSIS method and results can be seen in table 7.

Table 7 EV/PHEV cars ranking with TOPSIS method

Car ranking	cl_i	
A_5*(Tesla)*	$cl_5=$	*0.939827486*
A_3*(BYD)*	$cl_3=$	*0.473918823*
A_1*(Nissan Leaf)*	$cl_1=$	*0.170427866*
A_6*(Mahindra)*	$cl_6=$	*0.155902971*
A_2*(Mitsubishi)*	$cl_2=$	*0.124152817*
A_4*(GM)*	$cl_4=$	*0.117993695*

Results of TOPSIS and PROMETHEE methods are not the same and this difference is because of conservative perspective of TOPSIS. TOPSIS is about to minimize the risks, but PROMETHEE is about logical enrichment of decisions. Comparison the results of these two methods can be seen in table 8. Noted that PROMETHEE method is more reliable for decision making. These results can acquaintance car manufacturers of Iran to current situation of electric cars in the world and guide them to remove weak points of these six significant cars in their next products and it can be used as a part of their R&D roadmap.

Table 8 Comparison EV/PHEV cars ranking with TOPSIS & PROMETHEE method

	TOPSIS		***PROMETHEE***
Ranking	A_5*(Tesla)*	**Ranking**	A_3*(BYD)*
	A_3*(BYD)*		A_6*(Mahindra)*
	A_1*(Nissan Leaf)*		A_5*(Tesla)*
	A_6*(Mahindra)*		A_2*(Mitsubishi)*
	A_2*(Mitsubishi)*		A_1*(Nissan Leaf)*
	A_4*(GM)*		A_4*(GM)*

4 Discussion

A successful roadmap must conform a clear statement of the desired outcome followed by a specific path and milestone for attaining it. This path should include the 5 components as shown if fig.14.

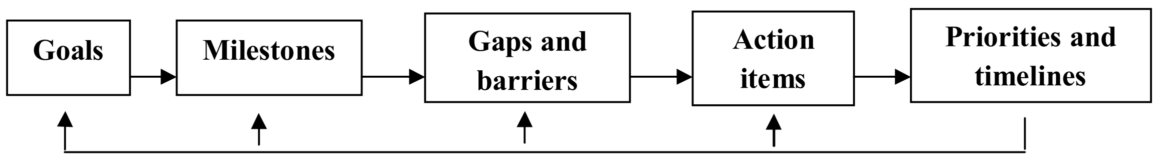


Fig.14 Elements of a successful roadmap [1]

Previous works are mostly discussed goals and milestones [31, 32]. The logic of roadmap in fig above is a chained relationship and each step enables next step. Feedback is also an important concept in this logic that makes road mapping a living process. Road mapping is the evolving process of creating and implementing a roadmap and monitoring and updating it as necessary [1]. This process is often as important as the resulting roadmap; it engages and aligns diverse stakeholders of process in a common action, sometimes for the first time. By getting interested parties to work together towards shared goals and results, the process can build relationships that have a significant, lasting effect long after the roadmap is published [1]. We must note that, core of knowledge and competencies (the black box) is the most precious activity of road mapping and this capability develops in two last steps (action items & priorities and timelines) [33]. Previous researches did not discuss this issue with detail. In this paper we discussed priorities as the most powerful enabler of road mapping process and this examination was done on electric and plug-in hybrid electric vehicles technology roadmap.

These cars market is indeed an important emerging market with considerable share of market, so it is essential for this area manufacturer to focus on the right market. This paper aimed for transparent this issue and examined acquisition layer and battery was selected as the major technological challenge of roadmap, then ranking of ion-lithium batteries was done. For being more informative, we also did ranking of six significant EV/PHEV cars. This method of ranking can be used as a guidance framework for next researchers a mean for prioritization.

5 Conclusion

This paper reviewed literature of road mapping and specially technology road mapping. Then we proposed a method for identifying priorities in lowest layer of technology roadmap. When a program or an international roadmap is on a special area of technology is going to launch, corporations all over the have a tendency to follow its regulations and instructions. The point is that small corporations with limited access to resources of different types cannot exert to action all items of roadmap. They must define their priorities and timelines according to their own capabilities. In this research we examine EV/PHEV technology roadmap and the most hurdle technology to develop in this roadmap is battery technology, so ion-lithium family as the most efficient family selected. Five (most probable to develop) batteries of this family were ranked from six technical features. Firms, according to their priorities can utilize the results of this ranking to develop batteries with their desire technological perspectives. We also did a comprehensive ranking of six most EV/PHEV cars sold in 2011. The ranking aims to indicate a benchmark. Car manufacturer can use this information to notify current situation of these cars and use them for future development. Finally, we note that this method is essential for all R&D units and manufacturer to gain an appropriate share of market. We hope that this result could help to more organized planning in acquisition layer of roadmaps in utilizing international roadmaps.

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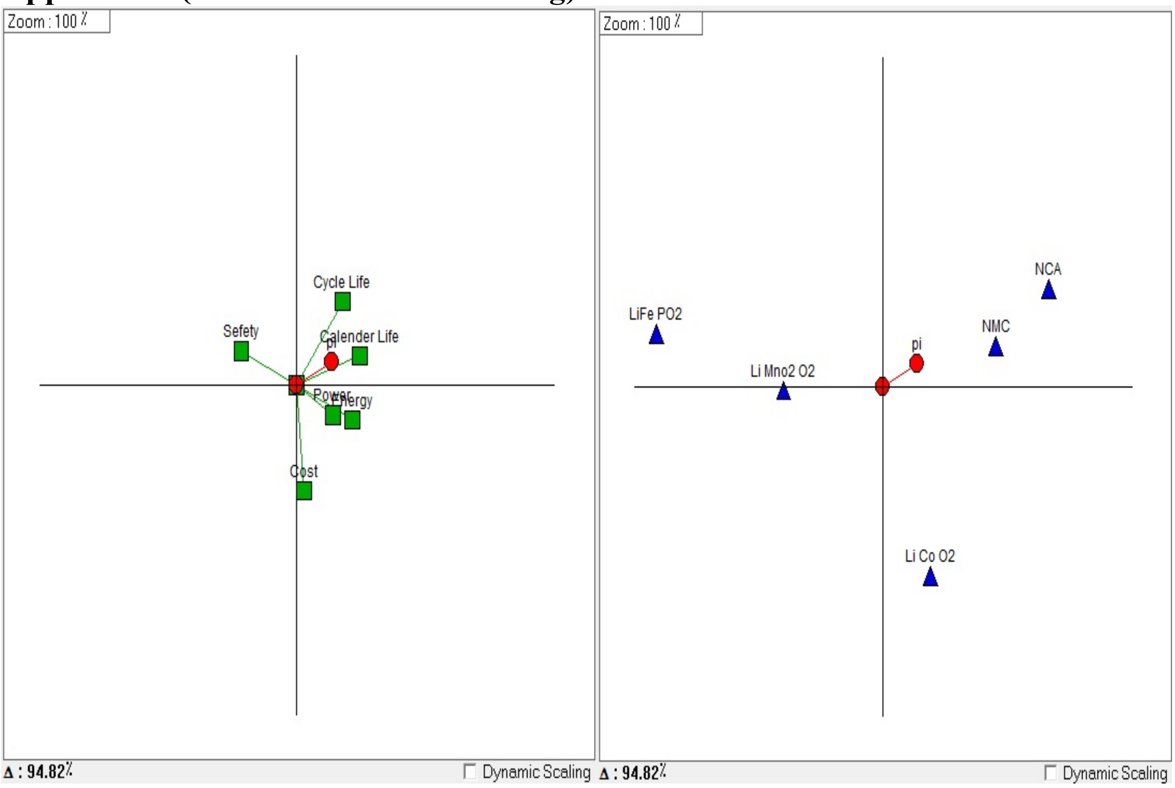
Appendix 1 (Batteries GAIA modeling)



Appendix 2 (EV/PHEV cars GAIA modeling)