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# **Individual Project Paper**

# Decision Model for Mobile Phone ODM (Original Design Manufacture) Vendor Selection

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#### ABSTRACT

Mobile phone has become an indispensable part of human being's daily lives. Triggered by the first launch of iPhone since 2007, the mobile phone industry has prospered and attracted many manufactures from other electronic industries. With past strong experience in PC related ODM manufacture experience, Taiwan ODM manufacturers gain great competence to acquire large and constant ODM/EMS orders from leading mobile phone vendors. They utilize ODM vendors' capabilities to provide emerging market with cost competitive products and wider product portfolio. Therefore, an effective ODM vendor selection model is critical to ensure the success of product launch and the quality level. The goal of this research paper is to establish a decision model for mobile phone ODM vendor selection.

An Analytic Hierarchy Process (AHP) model was selected to design an appropriate ODM vendor performance evaluation model which allows the mobile phone branding company to choose the best suitable ODM vendor. An expert panel of 5 experienced project managers helped on the model development and scoring process for 3 selected vendors. The results showed Vendor 3 has the best performance contributed by its most outstanding performance in Production Quality Criterion. R&D Capability is the most influential factor toward the decision at Focus Area level and Pricing Criterion impacts the Focus Area most.

Although this research paper had demo the effectiveness to use AHP model for ODM vendor selection, the simplified hierarchy structure and selection of expert panel composition might affect the accuracy and applicability of this methodology. A more detailed hierarchy structure and comprehensive factor elements along with a more diverse expert panel composition shall be used to examine the effectiveness of this methodology as future research.

#### **INTRODUCTION**

Taiwan mobile phone ODM industry had been flourished since 2004. The global mobile phone market was estimated as 1.6 to 1.8 billion users during that time. Thanks to the technology improvement on engineering and technology, the popularity of 3G mobile phone was boosted after several killer product launches, such as Motorola RAZR series. After the first launch of iPhone in 2007, the popularity of iPhone further triggered the global demand of smartphone. To fulfill the increasing demand from emerging markets, such as South America, East Europe and India, many branding companies started to make low to mid-range products. This means the needs to reduce the product cost and product lifecycle. With past strong experience in PC related ODM manufacture experience from late 1980's to early 1990's and the utilization of vertical supply chain resource, Taiwan ODM makers had owned great competence at that time and acquired large and constant ODM/EMS orders from leading mobile phone vendors, such as Motorola, Nokia, Sony-Ericsson, Siemens, Alcatel, Panasonic and LG. In 2016 Q4, Taiwan ODM/EMS manufactures shipped 13.82 million units [1].

Most branded mobile phone companies usually cooperate with more than one ODM vendors at the same time on different product so as to reduce the cost of internal R&D and manufacture cost while maintaining rich product portfolio for the market. A smartphone project development lifecycle is usually 6 to 9 month long, depending on the design complexity in both hardware and software. Thus, the ODM selection process usually takes place once in a year or at the beginning of each new project bidding. To ensure the performance and quality of the product delivery by the ODM, the ODM selection process needs to be conducted carefully to

make sure all aspects of criteria have been reviewed and considered. Of course, the best performance ODM vendor does not always guarantee the success of the project. However, it would decrease the risk from the ODM vendor's service quality and operation process management.

The goal of this research project is to establish an AHP model for ODM vendor selection process with the input from an expert panel which is composed of five experienced product managers and project managers in mobile phone industry. The AHP hierarchy includes different levels of decision elements for ODM vendor selection process. These decision elements were collected from several mobile phone branding companies. The effectiveness of this decision model would be affected by the chosen decision factors and the assigned score to these factors. After reviewing and discussing with the expert panel, it had narrowed down to the most influential set of criteria elements. The experts then provided quantified values for their subjective judgment about the impact of each criterion elements on the next level of the decision hierarchy. Also, based on their previous co-work experiences with these three ODM vendors, they provided their assessment for the performance of these three ODM vendors. These experts were also involved in the result interpretation. This model chose three leading mobile phone ODM vendors as the selection candidates as the example in this selection model. The expected result of this project is to provide an effective decision model tool for mobile phone manufacturers for their future ODM vendor selection. They would only need to provide the performance score for their new ODM vendor candidates into this model for future usage. They

could also adjust the criteria elements based on the new project situation. However, the relative impact score would need to be re-evaluated accordingly as well.

### **METHODOLOGY**

Performance and quality measurement and evaluation is the process of quantifying the effectiveness and efficiency of the objects by using several quantifiable factors from both tangible and intangible viewpoints. It is important that the measurement process is defined appropriately to align with the company's strategy and avoid the subjective human judgment in determining the relative importance of evaluation factors. From the perspective of capability and experience, the evaluation would focus on different areas including company business level, hardware and software competence, and production management. In this research paper, analytic hierarchy process (AHP) model is developed to incorporate the decision factor hierarchy. The hierarchy is used to describe how changes in priority of a criterion at upper levels would affect the priority of criteria at lower levels. It allows the decision makers to visualize the problem systematically in terms of relevant criteria in sectors. Five experts in mobile phone industry had helped to provide their pairwise comparisons for criteria in each segment and the ODM performance scores. This process represents how to use this model for ODM vendor selection.

Introduced by Saaty, AHP model was designed to address how to determine the relative importance and impact of a group of multi-dimension criteria for a decision problem. The process incorporates judgment on both tangible and intangible criteria which are possibly

either qualitative or quantitative. In literature, there have been some studies using AHP as the evaluation model for ODM vendor or supplier selection. A research done by Tahriri et al. showed that using AHP process could improve and assist decision making for resolving the supplier selection problems and for choosing the optimal supplier combination [2]. Another research done by Chia-Chi Sun was to use fuzzy AHP and VIKOR techniques to build a conceptual framework for measuring the business performance of notebook computer ODM companies in Taiwan [3]. This research showed that supply chain capability and manufacturing capabilities are the top two indicators for the notebook computer ODM companies' performance.

#### A. Development of Model Hierarchy

An expert panel which consists of 5 experienced mobile phone industry experts contributed to the model hierarchy development. The members comprise 2 branding mobile phone companies and 3 ODM company experience. Two of them are project hardware PM and another two are project software PM. One is the business relationship manager in mobile phone branding company and had worked as a hardware project management before. All of these experts have more than 10 year work experience in mobile phone industry in Taiwan.

To establish the model, first round used open-end style which requested the expert panel to brainstorm the related impacting factors in ODM selection process. Feedbacks were discussed and provided separately to avoid the influence to each other. Existing ODM performance evaluation processes from three branding mobile phone companies were also referenced in this

scope. After data was collected, a preliminary categorized decision structure is designed as

## below Figure 1:

Level 1	Level 2	Level 3			
Company evaluation	Organization	Culture			
		Project management maturity			
		Mian product roadmap			
		Product strategy and competition			
		Previous redibility			
		Standardization (ISO 9001)	Level 1	Level 2	Level 3
		Decision making	Hardware Competence	Capability	Acoustic
		Level of vertical integration			Antenna
		Rick management			Baseband
		Fiss management			Optical
		Financial health			RF
					Mechanic
	Resource	Availability			and the second sec
		Capability		Experience	Platform proven record
		Distribution			New technology
		Capacity			Environment certification
		Leading technology			Failure rate level
					1
	Dusianas	Communication in the summer of the second	Software Competence	Capability	Development process (TTM)
	business	Commercial terms (payment terms)			Development tools
		Main market/customers			Inhouse lab testing
		Pricing (NRE, Direct cost)	-		Flexibility in development
		Certification cost			Verification quality
		Tooling fee			Field test support
		IPR/Royalty		Province of	Platform annual month
		Sample devices		Experience	Pratronm proven record
		1 Mar and any make			Logorcennicate
		Life relation take			Operator approval

Level 1	Level 2	Level 3
Production	Supply chain	Strategic supply chain partner relationship
		Cost competitive
		Forecast flexibility
		Fulfilment & Production
		2nd source phase-in
		device partner management
		Material lead time
		Material quality
	Facotry	Capacity
	1 4 4 4	Certification
		Dedicated production line.
		Lead time for ramp up
		Clean room
		Production quality
		RCA quality

#### Figure 1 – Decision Criteria Selection Draft List

After reviewing with panel members, the decision criteria are further narrowed down based on its influence power to the impact on the vendor options. The reason to simplify these criteria is to make sure the final selection score could have sufficient difference between each ODM vendor. Figure 2 shows the final list of criteria.

Level 1 - Objective	Level 2 - Focus	Level 3 - Criteria	Level 4 - Vendor options
Company Evaluation	Business	Pricing (NRE, Direct cost)	FIH
		Commercial terms (payment terms)	Arima
		Life return rate	CEI
	R&D Capability	Hardware engineer competency	
		Software engineer competency	
		Operator approval experience	
		Platform experience	
		Certification experience	
	Supply Chain	Cost competitive	
		Strategic partner relationship	
		Material lead time & quality	
	Prodution	Capacity	
		Certification	
		Production quality	

Figure 2 – Decision Criteria Final List

The hierarchy is structured into four levels listed as below:

- Objective level presents the goal of this model to select the best performance ODM vendors among the candidates. The selection decision would incorporate all different viewpoints of the selection criteria from all levels.
- 2. Focus level contains the areas on which the evaluation of performance would emphasize. Each area is usually owned by different departments in the organization. Based on the characteristic of each project, there would be different level of impact by each focus area. For example, for a low-end product, business focus would have higher impact than the R&D engineer capabilities because the vendor needs to be competitive on the product cost including labor, material and productions. On the other hand, if the project is involved with new technology or material usage, the focus on R&D capability and production would be higher to ensure the development quality for the project success. To simplify the scope of this research paper, the performance evaluations for these vendor candidates are reviewed from overall assessment viewpoints.

- 3. Criteria level consists a diverse range of quality and capabilities. Each criterion contributes to the performance result of the focus level which it is associated. Brainstorming process with experts from different background provided a set of criteria. Evaluation criteria of the ODM and supplier vendor selection process from three mobile phone companies were also referenced as the complement to the expert panel's limited viewpoints. However, not all criteria would be included in this model to avoid the complexity of calculation. A limited set of criteria which only consist strong influential factors were chosen at the end.
- 4. Vendor option level includes three leading mobile phone ODM vendors in Taiwan. All the members of the expert panel had co-work experience with these three vendors on different projects. This allows them to provide the best assessment result to the performance evaluation for these three vendors. Although the assessment is from individual subjective viewpoint based on their working experience, the inconsistency analysis would be used to mitigate such possible situation.

#### B. Development of Evaluation Criteria in Each Hierarchy Level

The final 4 selected focus areas are grouped from Level 1 and 2 of Figure 1 by categorizing similar criteria and perspectives together. The criteria elements were classified based on its category to the focus area of the upper level. That expert panel was consulted for the final design of this hierarchy composition.



Figure 3 – AHP Hierarchy Structure

The notifications are defined as follows:

- **O**: the objective to choose the best performance ODM vendor
- Fk: the focus elements
- **C**<sub>kj</sub>: the criteria j for focus element k
- Vi: the ODM vendor options
- **k**: the number of focus elements
- *j*: the number of criteria
- *i*: the number of ODM vendor options
- $f_k$ : the impact of focus element  $F_k$  to the objective
- *ckj*: the impact of criteria Ckj to the focus element Fk
- vikj: the ODM vendor Vi's performance on criteria Ckj

Synthesis for overall impacts of ODM vendors' performance can be obtained by the following matrix operation:

$$P_i = \sum_{i=1}^{I} \sum_{j=1}^{J} \sum_{k=1}^{K} v_{ijk} * c_{kj} * f_k$$
, for  $i = 1,...,I$ 

, where  $P_i$  is the overall performance score for ODM vendor i

The definitions of the selected focus area and criteria are summarized in the following three sections of levels.

#### Focus level

**F1: Business** element includes the factors which impact the ROI of this project and the revenue for the company. The direct factors would be the related cost for the project development and product manufacturing at the factory. The indirect factors are the financial transaction terms whether it is in favor it is in favor of the vendor side or the customer side. Also, how flexible the vendor is willing to accept the requested terms is considered. Furthermore, there is also cost involved after products are sold to the market. It would include after sales service, the warranty cost and what is the commitment level to the product quality.

**F2: R&D Capability** is also the most import area when evaluating the performance of an ODM vendor. To develop mobile phone products, it generally requires electronic, mechanic and software engineers. The previous experience on the same development software platform, cellular network operator approval experience and lab/logo certification capability could be leveraged to shorten time-to-market schedule.

**F3: Supply Chain** includes how the vendors manage and improve its supply chain process across suppliers, company and customer cooperation to fulfill customers' order faster and more efficiently. The effective supply chain management is the key to ensure the success of

production and global launch process. The power with their strategic partner relationship would also be influential on critical hardware component price and delivery lead-time schedule. **F4: Production** is related to the factory process management and manufacturing activities. Most Taiwanese ODM vendors set up their factories in China region to save the labor cost. Most of their material suppliers are located in China as well. This would allow them to save the material delivery lead time and shipping cost to their logistic process. However, it would add the complexity to the manufacturing process because of the possible risks and problems from the material delivery process at the same time. The communication oversea and culture difference add more potential problems to the project management although Mandarin is the same official language in China.

#### Criteria level

**C11: Pricing** involves the direct cost of this project. It may include NRE (Non-recurring Expenses), MVA (Manufacturing Value Add), BOM (Bill of Material), and tooling costs...etc. Based on these cost, business analyst would estimate the CoS (cost of sales) for one product to be manufactured by this ODM vendor and to compare with the business target cost for the selection. Some companies might set up a reasonable target for internal and a stretch target to ODM. This would allow potential reduction in CoS while increasing the margin value of each product.

**C12: Commercial terms** are about how the payments are made from the vendors. Normal practices are O/A (open account) 30 to 90 days. Sometimes, ODM vendor would propose to reimburse its NRE cost with the first mass production shipment, such as the first million devices

payment. This is usually for the projects which are estimated for large sales volume and ODM would aim for the greater revenue at later stage.

**C13: Life return rate (LRR)** is used to control vendor's production quality commitment. It is agreed in the contract which will cause penalty to the ODM vendors if their accumulated product return rate exceeds this agreed rate after product EOL (end of life) which is normally two years. The higher LRR is, the more cost to handle the returned products need to be undertaken by the mobile phone companies.

**C21: Hardware engineer competency** considers the ODM engineers' capability in the areas of electronics, mechanical, antenna, RF, acoustic and optical. It depends on the target selling-point of the product feature to have different emphasis in these areas. For example, a narrow-boarder hardware design would cause great challenge to antenna and RF development. A water-proof design would require experienced mechanical design knowledge.

**C22:** Software engineer competency focuses the software engineers' capability in platform driver software integration with the lower hardware layer and application framework integration with the OS platform layer. The quality of the software development directly impacts the smoothness of later field test and operator lab verification processes. Also, at the second half part of the project development schedule is highly depending on how fast the software engineers could resolve the software bugs.

**C23: Operator approval experience** impacts the speed of operator required feature development and the operator compliance lab verification. Nowadays, the major shipment volume is contributed by operator orders. Whether this ODM vendor has previous shipment proven record to target operators could enhance the success of operator verification approval.

**C24: Platform experience** is related to the development experience of the chipset platform such as Qualcomm and MediaTek. It would directly impact how the ODM vendor engineers are familiar with the platform design, development tools, development package release schedule, and the technical issue support process.

**C25: Certification experience** includes both logo and carrier network compliance certifications. Examples such as WiFi Alliance, Bluetooth logo, NFC, DLNA ...etc. are logo certificate. They are usually verified by independent 3<sup>rd</sup> party labs. It needs both hardware and software development to fulfill these requirements. While carrier network compliance certifications are GCF, PTCRB, and FOTA...etc. are to verify to ensure the compatibility to the local carriers' telecom network system.

**C31: Cost competitive** is about the offered prices of key components of the mobile phone which account for the major portion of the CoS. They usually cover LCM touch panel module, processor, camera module and mechanical materials. However, some of the key components such as the processor and camera module might be bought directly by the mobile phone companies instead because some components are used on multiple projects.

**C32: Strategic partner relationship** would influence ODM vendor supply chain's bargaining power on delivery quantity, lead time and price. When product manufacturing is at mass production phase, it is crucial to ensure the required materials are at no shortage concern, especially for the popular components such as Qualcomm processor.

**C33: Material lead time and quality** is based on previous performance on the material delivery lead time management and the quality control management process which impact directly on the production quality. Especially when most Taiwan ODM vendors choose to locate their

factory facilities in China, the effectiveness of material delivery management represents its supply chain management capability.

**C41: Capacity** refers to the production line capacity which ODM vendor allocate for this project. Usually ODM vendors' factories manufacture multiple customers' product at the same time. How much production capacity is allocated and whether dedicate production lines are reserved could impact the production process flexibility.

**C42: Certification** is about the factory manufacturing process management and control. Certifications such as ISO 9001 demonstrate its ability to consistently manufacture products which meet customers' quality requirements.

**C43: Production quality** shows the final outcome of resource arrangement and production process management in the factories. At production ramp up phase, senior QA (Quality Assurance) managers from Taiwan teams would fly to China factory to monitor and control the production process. Any critical quality issue found at ramp up phase would directly be a possible stop-shipment red flag.

**V1 to V3** are three leading mobile phone ODM vendors headquartered in Taiwan. They all have coworked with international branding mobile phone companies since feature phone age. Their previous successful project delivery records had secured their positions in mobile phone ODM industry when facing new competitors from China.

**V1**: Established in 2002, Vendor 1 is a subsidiary of the world's largest multinational companies in the field of manufacturing service providers (including EMS, ODM and JDM players). With the strength in vertical integration of key components, Vendor 1 had expanded the foundation from smartphone development to wearable devices and IOT products.

**V2**: Established in 1989, Vendor 2 has developed diversified range of products and services to strengthen investment scale in its original core business in telecommunication industry and in new field of technologies.

**V3**: Established in 1984 with focus on PC peripheral supply, Vendor 3 had grown to secure its status as a leading manufacturer of netbook PC, LCD products and smart devices in Taiwan.

### C. Validation of the Model

The expert panel helped to validate the hierarchical model and its elements at each level. Each definition of the elements was explained in emails to these experts. This also allowed them have sufficient background understanding for how AHP works before requesting them for weighted score allocation at the next step. Comments and feedbacks to the hierarchy structure and the viability of each element were taken to revise for the final model.

### DATA AND DATA SOURCE(S)

During the ODM project development process, it is the project managers who have the most involvement and interactions with ODM partners in the daily work. The performance and service quality of the ODM partner also deeply influence these project managers' work performance. It is the reason why expert panels were chosen from project managers. The same expert panel which earlier contributed on AHP model establishment were also invited for the data collection process. An online HDM tool provided by Portland State University was used. A website screenshot of the online tool is shown in Figure 4 below.



Figure 4 – Screenshot of Online HDM Tool

Each of the experts was provided a link which allows them to provide their opinions toward each criterion of the ODM selection model. The input process was done individually. Each expert would not be aware of what other experts' inputs are. This could avoid the potential influence from others for the weighted number assignment. In the web tool, these experts need base on their perspective judgment to assign a number between 1 to 99 for each criterion pair at each level. For each pair, the sum of the two assigned numbers under a node must be 100. Each expert needs to complete the weighted number allocation for all the nodes before they are allowed to submit the result to the system. Because these experts were involved in the AHP hierarchy structure establishment process, they were all familiar with the definition of each node. However, they were not informed the methodology of pairwise comparison to avoid potential manipulation of the assigned numbers.

## **ANALYSIS AND KEY FINDINGS**

In below section, the results of the model would be discussed in details. The data of pairwise comparisons obtained from experts' input were calculated with pairwise comparison method (PCM) algorithm.

#### **Objective Level**

At this level, the experts assessed the relative impact of each focus area to the ODM performance. The data which were collected from the online tool were compiled in the form of matrices as the result of PCM calculation. Table 1 shows the relative impact of each focus area to the ODM performance from each expert's judgment in the order of impact as R&D capability (0.31), Business (0.29), Production (0.22) and Supply chain (0.18). This means ODM vendor's R&D capability has the biggest impact on their performance. As shown in the last row of the table, the inconsistency of each expert is low (0 to 0.01), which indicates the consistency of each expert's answer. From the standard deviation column, we can notice the experts' opinion on Business Focus Area has more disagreement, compared with other three Focus Areas. Expert A specially allocated lower weight score because he thinks the business related factors do not have direct impact to how ODM vendors would perform in the project execution. Instead, this focus area is more related to the vendor company's business strategy.

Level-1 Objective	Expert A	Expert B	Expert C	Expert D	Expert E	Average	Stdev.
Business	0.18	0.32	0.34	0.28	0.32	0.29	0.064
R&D Capability	0.34	0.27	0.34	0.29	0.29	0.31	0.032
Supply Chain	0.2	0.18	0.14	0.19	0.18	0.18	0.023
Production	0.27	0.23	0.18	0.23	0.21	0.22	0.033
Inconsistency	0.01	0.01	0.01	0.01	0		

Table 1 – Relative Impact of Focus Area to the Objective

#### Focus Level

At this level, the experts assessed the relative impact of each criterion to the focus area. Similarly, the PCM calculation results are shown in Table 2 which represents the relative impact of each criterion to the focus area. For Business Focus Area, Pricing is the most influential criteria (0.46). It is because the cost of the project directly reflects the ROI result. For R&D Capability Focus Area, Platform experience impacts most (0.23) while SW and HW RD capabilities have relatively strong influence as well. This explained why these three ODM vendors are able to maintain their leading positions in this industry. For Supply Chain Focus Area, Cost competitive (0.39) is the most critical factor as it directly impacts the margin of the product. For Production Focus Area, Production Quality (0.39) is the most important element as it represents the ultimate quality outcome of the manufactured products. Among all the criteria elements, the Pricing criterion (0.46) is the most influential criteria based on expert panel's selection. The low inconsistency numbers (0 to 0.05) at this level indicate the experts had responded their answers in consistency. Among all the assigned numbers at this level, Expert C's input for Certification for Supply Chain Focus Area caused largest standard deviation. Compared with other experts, Expert C has more onsite support experience at China factory and thinks the certification such as ISO 9001 is a reliable and helpful indicator for production process quality control compliance of the vendors' factory.

Level-2 Focus Area	Expert A	Expert B	Expert C	Expert D	Expert E	Average	Stdev.
Pricing	0.5	0.48	0.44	0.42	0.48	0.46	0.033
Commercial terms	0.31	0.26	0.27	0.4	0.24	0.30	0.063
LRR	0.19	0.26	0.28	0.17	0.29	0.24	0.054
Inconsistency	0	0	0	0.03	0		
HW RD	0.21	0.19	0.18	0.18	0.25	0.20	0.029
SW RD	0.2	0.19	0.2	0.27	0.24	0.22	0.034
Operator experience	0.18	0.17	0.21	0.17	0.2	0.19	0.018
Platform experience	0.26	0.27	0.29	0.21	0.14	0.23	0.060
Certification experience	0.15	0.17	0.11	0.16	0.16	0.15	0.023
Inconsistency	0.01	0.01	0.03	0.03	0		
Cost competitive	0.44	0.45	0.28	0.33	0.44	0.39	0.078
Strategic partner	0.26	0.23	0.29	0.38	0.24	0.28	0.060
Material	0.3	0.32	0.43	0.29	0.32	0.33	0.056
Inconsistency	0.02	0.02	0	0.05	0		
Capacity	0.42	0.36	0.26	0.26	0.3	0.32	0.069
Certification	0.25	0.21	0.48	0.29	0.23	0.29	0.109
Production quality	0.33	0.44	0.26	0.45	0.48	0.39	0.093
Inconsistency	0	0	0	0	0		

Table 2 - Relative Impact of Criteria to Focus Area

## Criteria Level

Level-3 Criteria	Pricing	Commercial terms	LRR	HW RD	SW RD	Operator experience	Platform experience	Certification experience	Cost	Strategic partner	Material	Capacity	Certification	Production quality
Vendor 1	0.258	0.298	0.302	0.342	0.366	0.31	0.316	0.338	0.298	0.314	0.338	0.31	0.344	0.276
Vendor 2	0.454	0.316	0.36	0.24	0.29	0.254	0.304	0.262	0.348	0.342	0.252	0.306	0.288	0.218
Vendor 3	0.284	0.382	0.33	0.412	0,346	0.434	0.382	0.395	0.35	0.344	0.412	0,382	0.368	0.506
Stdev.	0.106	0.044	0.029	0.086	0.039	0.092	0.042	0.068	0.029	0.017	0.080	0.043	0.041	0.152
Average	0.332	0.332	0.331	0.331	0.334	0.333	0.334	0,333	0.332	0,333	0.334	0,333	0.333	0.333
CV	0.32	0.13	0.09	0.26	0.12	0.28	0,13	0.20	0.09	0.05	0.24	0.13	0.12	0.46
Inconsistency														
Expert A	0	0	0.02	0	0	0	0	0	0	0	0	0	0	0
Expert B	0	0	0	0	0.01	0.04	0.02	0	0	0	0	0	0	0
Expert C	0	0	0	0.01	0	0.03	0	0.02	0.01	0	0	0	0	0
Expert D	0	D	U	0.03	0.03	0.03	D	0	0	0	0	σ	0.01	0
Expert E	0	0	0	0.01	0	-0	0	0	0	Ð	0.01	0	0	0

#### Table 3 - Relative Performance of Vendors to Each Criterion

At this level, the experts assessed the relative performance and quality of each ODM vendor to each criterion. The PCM calculation results are shown in Table 3. Similarly, based on the inconsistency number (0 to 0.04) from the table, all experts showed consistency when allocating numbers to the criteria at this level. Among all criteria, Vendor 3 has the most outstanding performance in Production Quality (0.506). The second best is Vendor 2' best performance in Pricing Criterion (0.454).

Vendor 3's performance in Operator Experience Criterion (0.434) is the third. However, we could notice that the 8 out of 14 criteria have their coefficient of variation smaller than 0.15. This indicates these three vendors have similar performance at these perspectives. Having outstanding performance at some criteria which have higher weighted score will allow that vendor to differentiate itself from others. If the vendor does not have strength in technology capability or production quality, they might choose to pursue the low cost strategy instead. Figure 5 blow display the comparison chart of different performances in each criterion of these vendors. It is easy to observe Vendor 3 outperforms the other two vendors at most criteria. Vendor 1 is mostly standing at the second position. But Vender 2 shows great strength at Pricing Criterion.



Figure 5 – Relative Performance to Criteria Comparison

Vendor Option Level

Table 4 below shows the integrated score of all weighted elements of the AHP model for three vendor options as Vendor 3 (0.38) is the best performance when compared with Vendor 1 (0.31) and Vendor 2 (0.31). These scores represent the integrated performance evaluation result which incorporates evaluation factors from Level 1 to Level 3. The higher the score is, the better the performance of the ODM vendor is. The weighted scores for factor elements at each level are shown in Appendix A for reference.

Decisions	Vendor Option 1	Vendor Option 2	Vendor Option 3	Inconsistency		
Expert 1	0.35	0.28	0.37	0		
Expert 2	0.31	0.31	0.38	0.01		
Expert 3	0.31	0.3	0.39	0.01		
Expert 4	0.29	0.34	0.37	0.01		
Expert 5	0.29	0.33	0.37	0		
Mean	0.31	0.31	0.38			
Minimum	0.29	0.28	0.37			
Maximum	0.35	0.34	0.39			
Std. Deviation	0.02	0.02	0.01			
Disagreement				0.016		

#### Table 4 – Vendor Option Result Comparison

As discussed in previous section, Pricing Criteria is the second most influential element at Level

3. Although Vendor 2 is averagely at the 3<sup>rd</sup> position for most criteria ranked by the expert

panel, its outstanding performance at Pricing Criteria allows it to be competitive enough with

Vendor 1 which is averagely at the second position for most criteria. However, Vendor 3

maintains most its position as the number 1 for most criteria. As the result, Vendor 3 wins the

overall best performance.

### **Conclusion**

Among all factor elements from three levels, the average score is 0.32. The top three influential impact elements are Vendor 3's performance for Production Quality Criteria (0.51), the relative impact of Pricing Criterion (0.46) and ODM Vendor 2's performance in Pricing for Pricing Criteria (0.45). With the enhanced effect from high score (0.39) of Production Quality criteria at Level 2 Focus Area, Vendor 3 takes this advantage to win the leading position for the final result. Also, as discussed in earlier section, Vendor 2 got the lowest score in most criteria. But their strength in Pricing enhanced their competitiveness in this industry. In past experience, the projects assigned to Vendor 2 were usually less technology complexity but larger shipment volume. Therefore, ODM vendors should be aware of their position in this market when compared with other players so as to choose the best strategy. It is to know its own strength and weakness to create the differentiation from others.

This AHP model results were shared and discussed with the expert panel. They agreed the calculation outcomes are in line with their overall perceptions toward these three vendors. This evaluation model could be an effective tool for companies' future usage for ODM vendor selection. However, the scoring evaluation in this research is from a general point of view. Depending on the characteristics and emphasized features of the projects, the assigned score for the ODM vendors might be different as well. If a project is to have new technology innovation, the weighted score for R&D Capability Criteria would be higher. If the project is aimed for low cost segment to have larger sales volume, the Pricing and Supply Chain Focus Areas would become more influential. Therefore, companies would need to re-assign the numbers for all factor elements before applying this model.

#### FUTURE RESEARCH

When designing the AHP hierarchy structure and selecting the factor elements, the number of hierarchy levels and factor elements (nodes) were chosen to be within limited number to avoid the troublesome when experts are doing the score assigning at the data collection phase. It is because of the PCM algorithm, the increased number of hierarchy levels and nodes would greatly increase the required effort for the experts. This caused the model of this research signed as a simplified form to avoid such possible trouble for the experts. A more detailed structure and comprehend selection of nodes could be designed to examine the effectiveness of this methodology for future study.

Furthermore, the composition of the expert panel was mainly as project manager function role. This might impact the accuracy and applicability toward the assigned scores. Possible bias might be generated for the selection result. More diverse function role composition for the expert panel and stakeholders from different corporation levels could be adopted to incorporate different viewpoints and opinions. This would also be helpful to re-evaluate whether the design of this AHP hierarchy is appropriate.

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# APPENDIX-A The Score Result for Each Factor Element on Each Level



# <u>APPENDIX-B</u> The Final Integrated Score from HDM Online Tool

Decisions	Vendor Option 1	Vendor Option 2	Vendor Option 3	Inconsistency
Expert 1	0.35	0.28	0.37	0
Expert 2	0.31	0.31	0.38	0.01
Expert 3	0.31	0.3	0.39	0.01
Expert 4	0.29	0.34	0.37	0.01
Expert 5	0.29	0.33	0.37	0
Mean	0.31	0.31	0.38	
Minimum	0.29	0.28	0.37	
Maximum	0.35	0.34	0.39	
Std. Deviation	0.02	0.02	0.01	
Disagreement				0.016