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International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 3, Issue 4, April 2013)

Using Design Strategy Matrix based on Cognitive Usability Model for Mobile Devices in New Product Development

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***Abstract*—The mobile devices have grown rapidly with the progresses of Information Technology (IT) over past decades. As this reason, mobile devices have become the personal equipments(e.g. iPhone, iPad, Tablet PC and smart-phone). The designs for those devices can be traced to the original design-works of Personal Digital Assistant (PDA), which conceptual design integrated the critical issues with personal computer (PC) and mobility.**

Personal Digital Assistant (PDA) is a creative and original production for Internet Information Appliance (IA), so the study wishes to explore design issues (which are most important and critical factors for the developers) in the New Product Development (NPD).

Therefore, the study uses the Extension of Technology Acceptance Model (TAM) to extend a model called Cognitive Usability Model (CUM) to construct Design Strategy Matrix (DSM) for the decision-making among a lot of design factors, so the developers can use the indicators (e.g. real-time, integration & convenience) into DSM to reduce the complex design-combination based on those factors and to evaluate the capability and acceptance for the users.

The study uses the cases of the digital devices designs – "Mobile Addresses Book" and demonstrates the evaluation of the usability factors during the processes of design works.

***Keywords*—Technology Acceptance Model(TAM), Cognitive Usability Model(CUM), Personal Digital Assistant(PDA), New Product Development (NPD) , Design Strategy Matrix (DSM)**

I. INTRODUCTION

A. Background

The developers of the new product development (NPD) emphasize the creative and original designs based on their training and discipline [4,14], but the creativeness is time-consuming and high-costly processes. So it usually causes the delay and high-cost of the product development for enterprises. In view of marketing consideration, the consumers focus on the novel and fantastic products, which must be the important criteria in NPD. So the designing products should be sales oriented in NPD.

But this viewpoint always conflicts developers and makers in NPD. The implicit and explicit cognition among those roles including developers, makers, users and consumers are the bi-relationship between each other. Those conflictions among all roles usually delay the releasing day of time-to-market for those products [12], even reduce the sales-incoming by the individual standpoint caused by the cognition of the products' value between each others.

So the balancing each values between each role need a central agreement to convince all roles for the design functions in order to the sales achievement in the future. The interactions of bi-direction relationship will improve the efficiency and effectiveness in NPD, so the research issues for their co-operation among all roles are critical in the study.

B. Motivation

The new product developments (NPD) are very extensive domains, its area is not only the products designing and manufacturing, but also the consumers' value-optimization and satisfactions for users and consumers. In other word, matching both requirements and expectation have become the critical issues in NPD.

The designers in NPD always hope to be creative on their artifact instead of functions optimization, but the consumers choose the cheapest prices with the most convenient functions. As the reason, the conflictions among all roles in NPD teams usually exhaust the cost and the creativeness for new product designs. If we find the coordination of different design criteria, the endless cost waste maybe come to an agreement to achieve individual expectation each based on their values.

The study applies the methodology of the cognitive gaps model (CGM) [16] to explore the issues of cognition in each aspect of all roles to matching the mutual role benefits. In advanced, the different believes according to the discipline of the marketing maybe a new way to solve the cognitive problems. Based on this view, the driving powers of the consumers can be more clear and obvious for the developers to rethink the best niche of all roles.

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The problems in the study are more complex than the problems in CGM, because the coordination and domination among all roles needs the smart methodologies to arrange the all tasks in NPD processes.

So the study refers integrated usability model (IUM) [17,18] to solve such complex problems. The IUM can integrate usability issues in NPD. This model extends the cognition into usability, which can express the satisfaction after use behaviors.

The makers' desires are the revenues from the sales of products with matching the consumers' need instead of looking forward their creativeness. if the purchasing motivation & the purchasing behaviors follow with the usability and functions of the products, those factors must turn into the strategic guides for the developers. Therefore, the developers face the issues for the usefulness and the usability in NPD. Especially, for those issues on the cognitive usability among all roles.

For the reasons mentioned above, the study tries to find the cognitive usability among all roles and to transform the critical issues into the strategic planning in NPD. The study hopes to use an adapted model for the cognitive usability based on the issues mentioned above.

In summery, establishing a new model to solve cognitive usability issues is the central point in the study. The study finds technology acceptance model (TAM) [6,7] helpful in our study, but some differences from TAM exist because of the two roles involved in the profit concerned with the incoming of the consumers' purchase and the creative design of the developers.

The study uses a case study based on two products developments to derive an adapted model from TAM to solve the cognitive usability and the roles' relationship.

C. Goals

The goals of the study are listed following:

- Use the product design "Mobile Addresses Book" as the usability based on the mobile-usefulness and the instant the services.
- Construct an adapted model from technology acceptance model (TAM) to solve the cognitive usability issues for the strategies decisions in NPD.

II. Literature Survey

A. Background of Technology Acceptance Model

The researches about consumers' cognitive behaviors in marketing field proposed on previous researches included the theory of reasoned action (TRA) [1,2] , The results of the theory of planned behavior (TPB) [3,9] .

Davis proposed a new approach derived to technology acceptance model (TAM) [6,7] to point out the result of behavior intention influenced by consumers' attitude. Many literature survey proceed many related comparisons and discussions for these theories(e.g. TRA, TPB & TAM) including validation by empirical study.

Davis proposed TAM [6,7] as shown in Figure 1 on the discusses of technology acceptance criteria for users' attitude & behaviors with comparisons of TRA & TAM theoretical models in the dissertation. The results by empirical study validate the better explanation of the behavior intention than TRA.

Although the results of Davis' researches can't judge the discrimination of two models by the trial experimentation results for TAM, but the discrimination of the attitude and behavior intention proposes better explanations for TAM had.

For the reason mentioned above, Ajzen [2,3] proposes TPB to enhance and modify TRA. In advance, Mathieson [13] and Taylor [15] compare with TPB & TAM in a view of attitude & behavior intention of information technology and prove the better explanations of TAM than TPB by the empirical study.

Taylor uses empirical study [15] for TAM & TPB to prove the differences of results of Mathieson' researches [13] and finds the constructs about cognitive behavior control to enhance better explanation of attitude than TAM. For such results, Taylor and Todd propose that two constructs about objective norm and cognitive behavior control influenced behavior intention, in opposition to lack of two constructs for TAM.

According to literature survey for TRA, TPB and TAM arguments, the study wishes to apply TAM as the basis model including consumers' behavior and cognitive behaviors to offer a better explanation for IT derived products and relationship between IT characteristics concerned with each other.

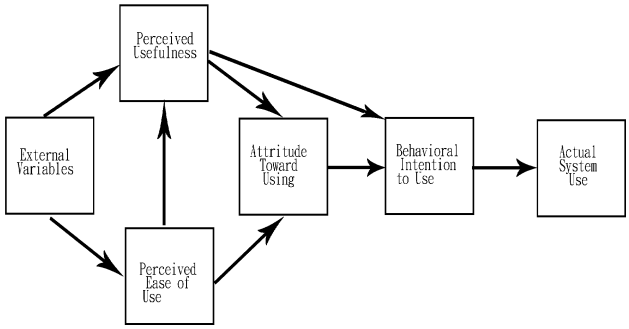

Figure 1 Technology Acceptance Model Theory

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B. Introduction of Technology Acceptance Model

Davis proposed the technology acceptance model based on TRA as shown in Figure 1 in his dissertation [6,7] to discuss the influenced issues of perceived usefulness and perceived ease of use for users of new information technology. TAM had described the ability of the efficient prediction and evaluation for information system (IS) users' behaviors including extensive explanations of IS acceptance behaviors (e.g. email, enterprise applications. WWW, web applications, online game) [5,8,11].

As the reason of feasibility & scalability, TAM constructs the reserved constructs as the external variables for the perceived intention but not direct to the attitude in the researches. The mechanism of TAM external variables enhance the scopes of TAM, those external variables include characteristics of system designs, involvement of users, training of job-workers, supporting documents, etc. .

Therefore, a new mobile applications or products owning the perceived ease of use & perceived usefulness with more positive attitude will enhance the possibility of behavior intention to use & actual use according to TAM.

C. Cognitive Gap Model

The related research about the extension of TAM is CGM [16] . The adapted model uses the perceived usefulness replace the perceived ease of use in TAM based on the functions approaches. The perceived value replace the usefulness in TAM with innovations approaches for the advanced considerations of the consumers. The two constructs have direct relationship between both and have direct relationships to attitude toward purchase instead of using. The attitude toward purchase will trigger the keys of behavioral intention to purchase due to the changed attitudes and closely to the motivation of the purchasing.

The related research in CGM as shown in Figure 2 proposed the validation for the actual use & continuous use after the purchasing products in NPD. In advanced, the validation of the products usefulness to the accurate users needs and the relationships of attitude toward purchase to actual product use as the mechanism of the feedback in CGM.

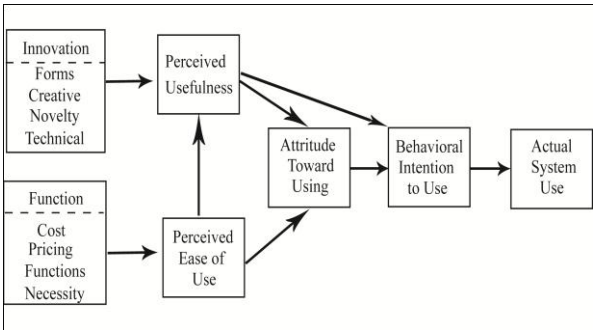

Figure 2 Cognitive Gap Model

D. Integrated Usability Model: the extension of TAM

The other researches are the integrated usability model (IUM) [17,18] . The adapted model from TAM uses the integrated and the usability as external variables for the integration and usability functions in NPD. It reduces the design criteria and transforms them into design guidelines.

The researches for IUM as shown in Figure 3 propose a methodology to reduce the complex criteria into the exact design guidelines for designers in NPD processes. By the way, the design works can be processed and be arranged the different jobs in different design stage [10]. So the methodology will help the developers to work more efficiently and effectively.

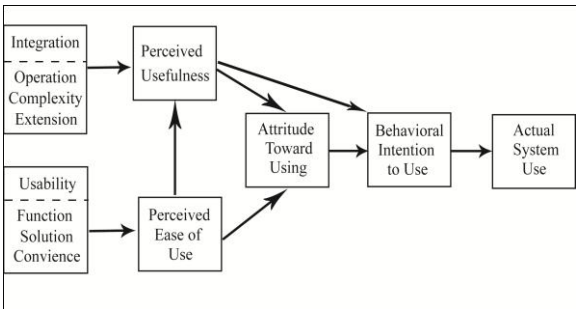

Figure 3 Integrated Usability Model (IUM)

III. CASE STUDY

A. User Requirements

The study uses "mobile-addresses book" as a case. The requirements of the case are described following:

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Scenery:

The business people always introduce themselves to their new friends or customers by giving their name-card to each other. The name-card have become a popular and easy way to keep the mutual personal information.

Therefore, giving name-cards to each other has become the serious problems when more and more name-cards received, in spite of using the digital devices (e.g. PC, PDA, Smart-phone, Tablet PC, Notebook) to keep the digitalized information transformed from name-cards. Those jobs have become more and more frequent and heavy for business people when the new friends or customers add their contact lists.

First, most business people still use the name-cards to inform and to keep the mutual personal relationship and communication-data. So the transformations and digitalization of those data from the paper-based name-cards can be eliminated and improved at all.

Second, querying contact lists for advanced use is difficult for them. Although some business people will use the name-card scanner to do those jobs, but those devices need desktop computer (PC) and other equipments to finish all processes, which are boring and time-consuming.

Third, business people face the problems from the bi-direction data-transformation. For example, Mr. Smith meets the Mr. John who is a manger and works at the A1-company. After the conversation, Mr. John give Mr. Smith a new name-card and tell him for his job changes to other. So the name-cards need to be transformed again. Mr. Smith still needs to know the history of Mr. John job's changes and related business relationship.

Fourth, the interactions between those business people need to record and reuse in the future. The digital-recorders and digital-cameras are very popular today. But integration problems of those personal data and the interactions still are the critical issues for business people during their business works.

The characteristics of the problems mentioned above are partially solved by some digital devices (e.g. PDA, smart-phone, iphone, iPad, tablet PC). But the critical problems are still existed including data-relationship integration, data-retrieving, multimedia data binding, etc. .

If business people can use only one device to solve those problems, the heavy-duty equipments for those business people maybe will be solved.

B. Translation of User Requirements

The developers summary the users requirements mentioned above into the function design requirements in the conceptual design of NPD.

The developers must translate those implicit needs from scenery descriptions into more exact requirement for advanced function design. We can see the function design requirements lists following:

- The automatic digitalizing process for the name-card information.
- The desktop computer (PC)operation seems to avoid.
- The mobility and portability for the device.
- The data exchange ability to others device.
- The standalone device matches the users' central needs.
- The necessary recording functions.
- The snapshot of photos functions built inside.
- The data-integration for add/delete/update name-cards information.

C. Translation of Function Design Requirements

Each developer will know that the function design requirements are too rough and uncertain for design-works. Because those function design requirements can be analyzed into different functions by each other based on their individual viewpoint. We know that the translations of the user functions are heterogeneous and difficult. The developers just expand the physical and functional criteria based on the function design requirements into the user requirements by using their design disciplines. So the user functions will be listed bellow:

- The non-desktop computer (PC) based operation
- The mobility and the portability.
- The data exchange to other devices
- The independent device.
- The recording functions.
- The camera functions.
- The instant-scanning mechanism.
- The automation integration mechanism.

IV. The Design Strategies

A. Usability Weight Pricing for Functions

The developers need to know what all requirements and functions are. First, the developers weight each function, so the developers need the measure methodology. The study creates a way to measure the function weight for usability.

The developers use the questionnaires to users for all possible functions. The users answers the prices which the function she/he wishes to spend.

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The limitation for the upper-bound of the purchasing spending for all functions is one thousand. Finally, the study counts all questionnaires, and calculate each function (e.g. average, maximize, minimize, etc.) as shown in Table 1. The final pricing resulting table of each function list following:

TABLE 1
FUNCTIONS PRICING WEIGHT

NO	Function Description	Price
F01	The device is mobile use	100
F02	The device is portable	50
F03	The exclusive design	30
F04	The automatic name-card scanning	160
F05	The OCR mechanisms for the content of the name-card identify	120
F06	The recording voice mechanism	120
F07	The Photography mechanism	130
F08	The Video Camera mechanism	120
F09	The data-sharing mechanism	50
F10	The address-book mechanism	120

B. Function Cost Estimation

The developers need to know what the requirements and functions are cheaper or expensive. So the study creates a table list to weight each function cost, but the study still needs the measure methodology. The study creates a way to measure the function weight for developers.

The developers use the function estimated lists to develop all possible functions. The developers estimate the possible work-hours which the function she/he will work for. The limitation is that the upper-bound of the total work-hours for all functions is one thousand. So we count all function estimated list and count and average each function cost shown in Table 2. The final functions cost table list bellowing.

TABLE 2
COST ESTIMATING WEIGHT

NO	Function Description	Estimated Work hours
F01	The device is mobile use	80
F02	The device is portable	40
F03	The exclusive design	200
F04	The automatic name-card scanning	60
F05	The OCR mechanisms for the content of the name-card identify	80
F06	The recording voice mechanism	80
F07	The Photography mechanism	80
F08	The Video Camera mechanism	80
F09	The data-sharing mechanism	220
F10	The address-book mechanism	80

The study uses the arithmetic to the price cost weight chart. The analyzed chart lists following as shown in Figure 4.

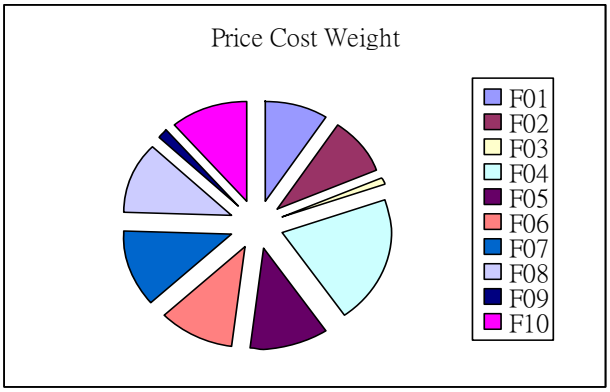

Figure 4 Price Cost Weight

C. Design Guiding

This study refers Table 1 and Table 2 to count the price/cost weight (P/C weight) shown in Table 3. The design functions can be reduced more simple criteria by same design approaches.

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TABLE 3
PRICE/COST WEIGHT

NO	Function Description	P/C Weight
F01	The device is mobile use	1.25
F02	The device is portable	1.25
F03	The exclusive design	0.15
F04	The automatic name-card scanning	2.67
F05	The OCR mechanisms for the content of the name-card identify	1.50
F06	The recording voice mechanism	1.50
F07	The Photography mechanism	1.63
F08	The Video Camera mechanism	1.50
F09	The data-sharing mechanism	0.23
F10	The address-book mechanism	1.50

We can find function F01, F02, F03 same, so the design strategy can merge the functional designs by the same design-skill into Table 3. The form design strategy can be created as shown in Table 4.

TABLE 4
FORM DESIGN STRATEGY

NO	Form Design Description	P/C Weight
DC01	Form Design	2.65
DC02	Name-Card Scanning	2.82
DC03	Digital Camera	3.13
DC04	The address-book mechanism	1.5
DC05	The data-sharing mechanism	0.23

D. Cognitive Usability Model (CUM)

The critical problems are how to evaluate those criteria according to importance or not. The users will not purchase and repurchase the device for those non-sense functions. Because more functions cause the high cost and complexity. This is a serious barrier for the marketing planning of those designing products in NPD. So the reasonable and acceptable functions for consumers and users are the best criteria as guiding to the developers in NPD.

The study proposes an adapted model called cognitive usability model (CUM) as shown in Figure 5 to design those questionnaires as constructs and collect the questionnaires results to analyze the constructs.

The statistics reports will show the developers what are the high-weighted criteria finally.

So the study can use many questions as constructs to collect the intention and thinking of the designing products in NPD as the external variables of TAM. Those external variables can describe sub-requirements of the design criteria at all.

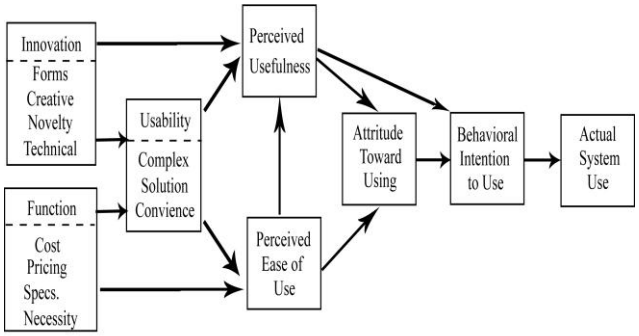

Figure 5 Cognitive Usability Model (CUM)

E. Design Strategy Matrix (DSM)

Although the developers use CUM to evaluate the criteria of designing products in NPD. The developers still need to conclude all questions and results to decide what are important in NPD. So the study creates some steps lists following:

First, the developers use questionnaires to ask users and purchasers (i.e. consumers and users) to answer their intention and the thinking of the designing products in NPD.

Second, the developers analyze the collected questionnaires to find the high-weighted criteria.

The study analyzes questionnaires and calculates those results into the design-criteria based on functional requirements as shown in Table 3 and form design guiding as shown in Table 4.

But the main problems are the design guides for the developers in NPD. So the study creates a design criteria validation table, which is called design strategy matrix (DSM) in the study, for counting the weight-values of those criteria and decide which design criteria should be realized in NPD as shown in Table 5.

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TABLE 5
DESIGN STRATEGY MATRIX

Strategy	Criteria	Innovation	Function	Usability
Form Design	Size	**	_	_
	Mobility	**	**	***
	Portability	***	_	**
	Luxurious	*	_	_
Name-Card Scanning	Automatic	***	***	***
	Total Solution	**	_	***
	Handy	**	_	_
	Visual Use	*	_	_
Digital Camera	Multi-Functions	*	***	***
	Resolution	**	_	***
	Controlable	**	_	_
	Usable	***	_	_
Address book	Easy to use			
	Data Sharing	***	***	***
	Composed	**	**	*
	Function	***	*	_
	Computer-Based	***	_	*
data-sharing	Data Share	**	**	***
	Intelligent Use	_	_	_
	Extension	***	***	**
	Standard	***	**	**

V. CASE STUDY

The study asks some business people for their experiences of using name-card to derive an operation-processes diagram of the users behaviors.

A. Users Behaviours Diagram

The developers will draw the operational flows diagram of using name-cards for business people as shown in Figure 6. So the whole flows diagram can transfer the detailed logical and physical functions and non-functions.

The developers will design the product prototype based on the constructed functions and non-functions.

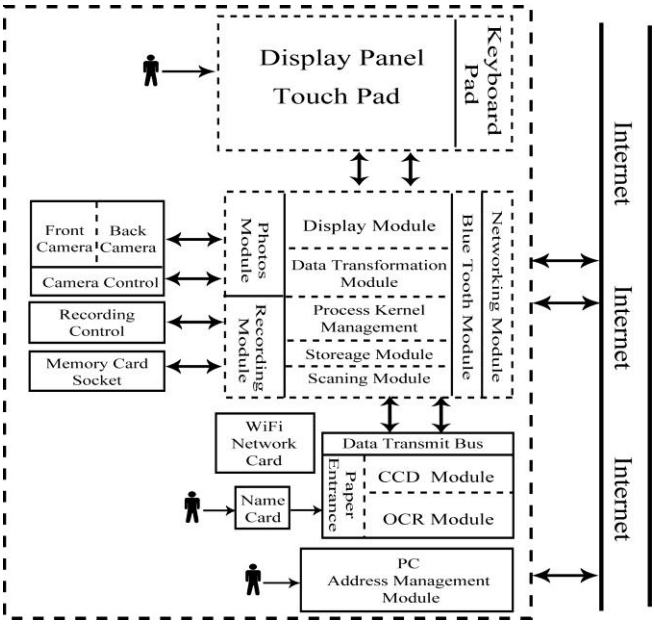

Figure 6 Users Behaviours Diagram

B. Form Design

The developers design the form of the product prototype according the operational flows diagram of using name-cards for business people as shown in Figure 6. But only the scenery of the operational flows diagram is not enough for the form of the product prototype, because of little information. So the study uses design strategy matrix (DSM) as shown in Table 5 to derive the automation and mobility approaches based on the leading roles.

The developers will compose the functional devices according the requirements decided by the strategy guides as shown in Table 1. The name-card detective feedback mechanism and digital camera will be added, the name-card scanning are the necessary functions. So the photo-taking and video-recording is putted on the internal space-room according to Table 4. The form-design prototype is demonstrated as shown in Figure 7.

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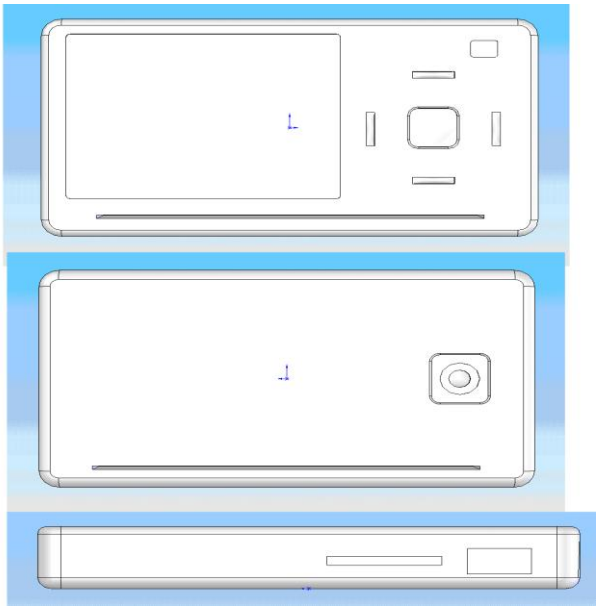

Figure 7 Form Design

C. Function Design

The developers design the form of the product prototype according the operational flows diagram of using name-cards for business people as shown in Figure 6 and Table 5. The detailed functions and form-design will be composed together to create the product prototype related the functions and non-functions.

The developers compose the functional parts according to the requirements mentioned above. The functions of the product design are demonstrated as shown in Figure 8.

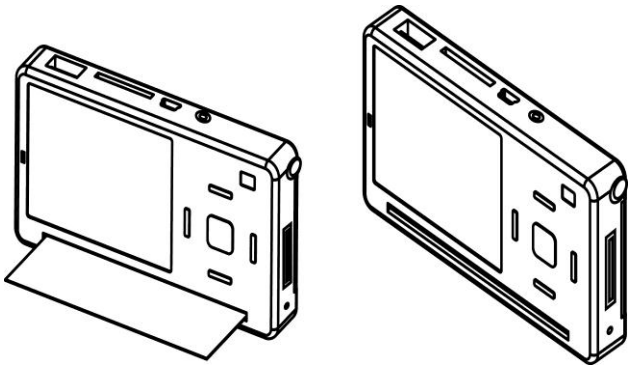

Figure 8 Functional Design

D. Integrated Product Design (Product Prototype Design)

The developers integrate all design works mentioned above into a complete product prototype design as shown in Figure 9.

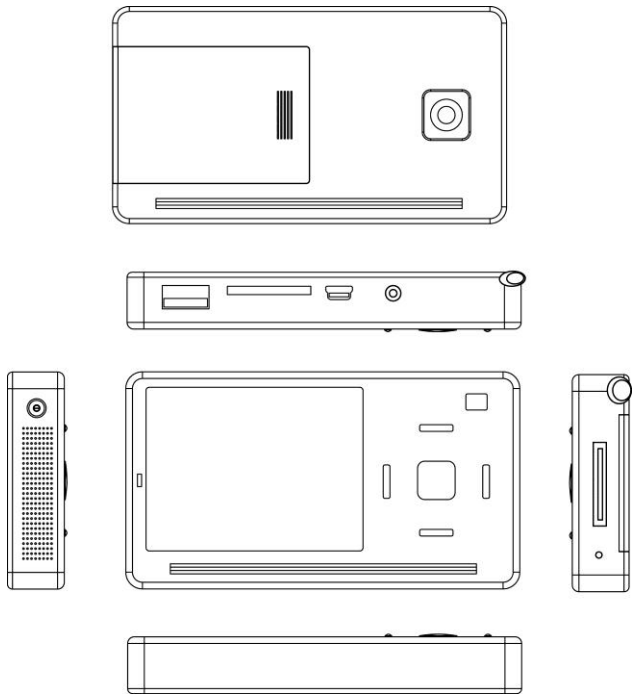

Figure 9 Product Prototype

VI. Conclusion

The study proposes the cognitive usability model (CUM) to build the constructs to weight the design criteria and uses those constructs to construct the questionnaire to weight the design criteria. Then the study uses design strategy matrix (DSM) to decide what are the most important design strategies for developers, consumers and users. Because the study' case in the research needs the usability-oriented to weight the complex users' functions and non-functions, so this new approaches offer a better methodology to solve the problems of cognition and usability of the products design in NPD. Therefore the study uses CUM to select the high weighted factors from the each design criteria. By the way, the high-weighted criteria can be extracted by CUM into the design strategy matrix tables. Finally, those design strategy matrix tables help the developers to do the right-thing and thing right during the processes in NPD.

The developers and marketing managers can also use CUM to evaluate the usability of the commercial products from the customers' using experience. So R&D department and sale-marketing department can also analyze the satisfaction of the consumers and users. Then the repurchasing behaviors will be predicted more exactly. The results will let the developers to focus on the exact users requirements during the design-processes in NPD.

Acknowledgment

The study was partially sponsored by NSC100-2218-E126-001, NSC99-2632-E126-001-MY3, NSC99-2218-E-126-001, NSC99-2632-E126-005-MY3, NSC100-2410-H-008-051-, NSC97-2410-H-008-039

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International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 3, Issue 4, April 2013)

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