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Integration Process of Industrial Design and Engineering Design

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***Abstract*—**Lately management strategy that put Industrial Design (ID) in its core is recognized more important, as technology and price alone cannot differentiate a product. The needs to shorten the time to develop a product also shorten the development period of ID, and it necessitates the ID process management. This research analyzes the status of integration process of ID and Engineering Design (ED) of office equipment that requires the collaboration of ID and ED to clarify the issues for the efficiency of the development and to propose solutions.

***Keywords*—**Industrial Design (ID); Engineering Design (ED); Integration process; Office equipment

I. Introduction

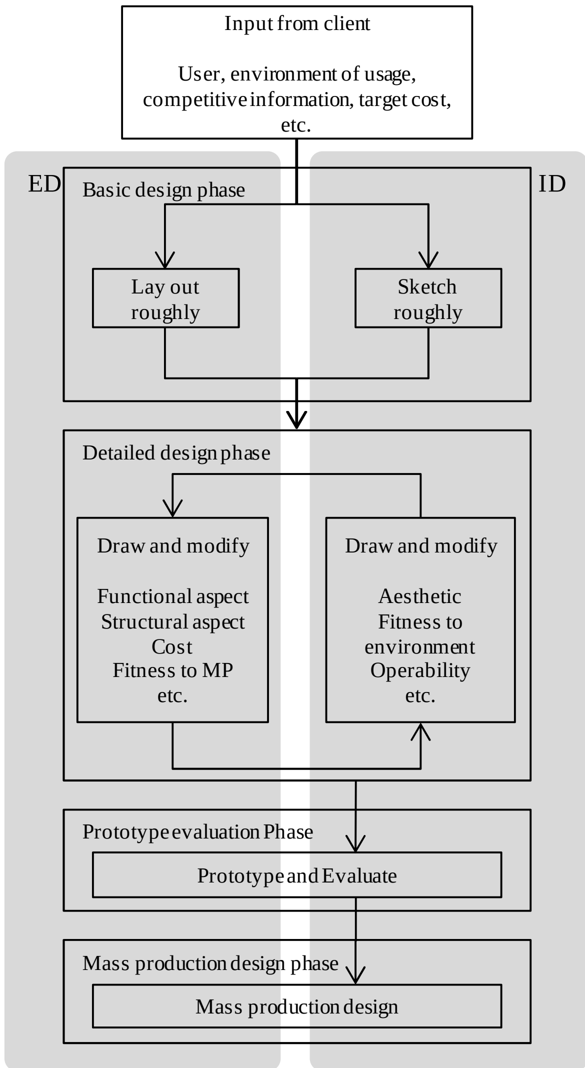
LATELY management strategy that put Industrial Design (to be abbreviated as ID) in its core is recognized more important, as technology and price alone cannot differentiate a product. The needs to shorten the time to develop a product also shorten the development period of ID, and it necessitates the ID process management.

While there are ID centric living commodity that is difficult to be differentiated by function and performance in one hand and Engineering Design (to be abbreviated as ED) centric industrial equipment that is actively differentiated by function and performance in another, Engineering Designer (to be abbreviated as EDer) and Industrial Designer (to be abbreviated as IDer) collaborate in the development process of office equipment that is positioned in between two type of products.

However, as the objectives of EDer and IDer are not the same. Many disorders may come up in the integration process of the ED and the ID. Therefore this research aims to analyze the disorders and find out the cause of them. And purpose of this research is to propose the resolutions for more efficient development.

II. Integration Process in a Product Development

In the integration process of the ED and the ID, as shown in Fig 1, EDer and IDer create drawings and rough sketches to fulfill the requirements of the client (management, project chief etc.) to begin with, and resolve the problems and issues. The process is divided into the steps of "Basic Design Phase", "Detailed Design Phase", "Prototype Evaluation Phase", and "Mass Production Design Phase".



Source: sugiyama[1]

Fig. 1 Integration process

III. Review of Existing Studies

Effects and the utility of the ID have been studied for a long time, including Lorenz [2], Yamamoto[3]. There are studies on quality evaluation criteria of design [4][5], design methodology [6][7]. The researches and developments of the computer assisted ID have been attempted [8][9]. And furthermore,

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ESKO KURVINEN[10] outlined critical settings and situations that should be taken into account when industrial design is introduced to engineering-oriented product development, but no study of problems in design integration, namely studies of the causes and the resolutions of the causes in the cases where retrogression to the previous steps takes place, has been presented.

IV. The Definitions and Functions of ED and ID

This research define ED and ID as follows..

Definition of ED is ‘Exercise scientific principle, technical knowledge and creativeness to achieve the intended functions most economically and efficiently. ’

Definition of ID is ‘Providing value by means of visual and tactile aspects of the product to industrial products. For example function of ED is to 'Make products compact' and 'Create functions', and function of ID is to 'Make products look as compact as possible’ and 'Arrange functions appropriately'.

V. Mutually Recognized Problems between ID and ED

In order to clarify the problems in integration process, as the first step, problems of the partner from the view point of EDer and IDer respectively are extracted with questionnaire and interview.

With a questionnaire of “What are the problems of IDer from the view point of EDer”, 123 problems are gathered from 16 EDers in an office equipment manufacturer A. Factor analysis of these problems clarified that EDer perceived that problems came from an extra focus on aesthetic and that IDers lack “considerations for mass production and users”. And the problems of EDer from the view point of IDer are collected from interviews with 2 IDers in the company A and 3 IDers of 2 design firms, and they perceived that EDers place priority on cost rather than ID quality.

VI. Problems in Integration Process

Take one model of document scanner as a sample of office equipment; logs of the problems were analyzed.

The document scanner was chosen, as it has global users in the market and Japanese manufacturers have primary share in it. Therefore the research result will make a good reference for other products that aim the global market.

As a result of this analysis, 31 problems are classified under 7 types as below. Numbers shown in parentheses are numbers of problems.

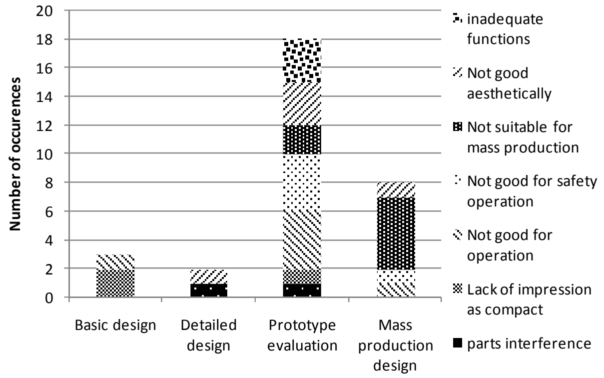
- Not suitable for mass production(7)
  5 problems are pointed out by ED
- Not good for operation(6)
  4 problems are pointed out by ED and 2 by ID
- Not good aesthetically(5)
  All problems are pointed out by ID
- Not good for safety operation(5)
  All problems are pointed out by ED
- Inadequate functions(3)
  All problems are pointed out by ED
- Lack of impression as compact(3)
  All problems are pointed out by ID
- Parts interference(2)
  All problems are pointed out by ED

IDer and EDer pointed out the same problems that were mentioned in the previous section and justified the research result of the questionnaire and interview.

VII. Analysis of the Problems

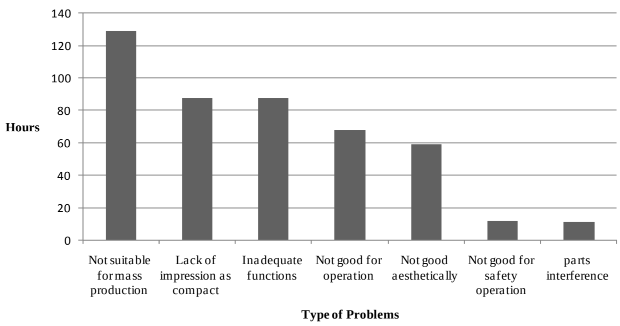
The figure 2 shows the number of problems in terms of phase of integration process. As it shows that many problems are found after a prototype was made. This indicates that problems are not detected adequately in early stage of development.

The figure 3 shows the time required to fix the problems in terms of the type of problems. “Not suitable for mass production” requires 129 hours to fix the problem, and both “Lack of impression as compact” and “Inadequate functions” requires 88 hours. “Not suitable for mass production” is mostly found in the later stage of mass production designing phase, and this constitutes the primary issue to improve efficiency in development.



Source: sugiyama[1]

Fig. 2 Number of problems in terms of phase of integration process



Source: sugiyama[1]

Fig. 3 Time required fixing the problems

VIII. Analysis of the Causes of the Problems

The causes of the problems were analyzed with a factor analysis method with 7 EDers and 1 IDer, and the primary causes of these problems were revealed. The results are shown as follows.

- Cost of manufacturing and investment amount are not a subject of IDers' performance evaluation
- Required margin vary by die machining department
- Too much expectation of progress of manufacturing technology
- Too much reliance on evaluation using prototype model
- Requirements of mass production restricts ideal operational layout
- The lack of cooperation between EDer and IDer

And resolutions were discussed and suggested by the same members.

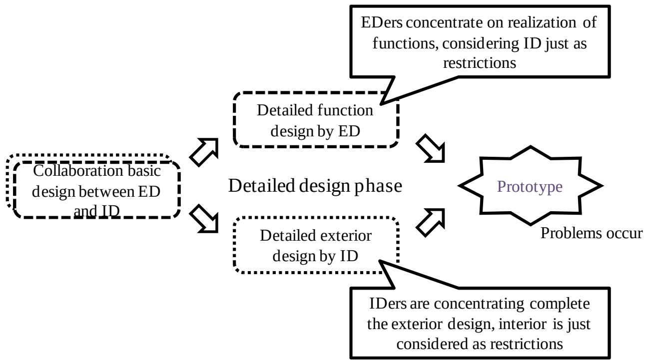
- Cost of manufacturing and investment amount are not a subject of IDers' performance evaluation
  - ⇨Include cost of manufacturing and investment amount for deliverable as a subject of IDers' performance evaluation
- Required margin vary by die machining department
  - ⇨Pre-agreement of margin with die machining department
- Too much expectation of progress of manufacturing technology
  - ⇨Collection and share of information of leading-edge technology of manufacturing
- Too much reliance on evaluation using prototype model
  - ⇨Practical use of human technology
  - ⇨Practical use of simulation technology
- Requirements of mass production restricts ideal operational layout
  - ⇨Collaboration with Manufacturing department
- The lack of cooperation between EDer and IDer
  - ⇨Cross examination of the design by EDers and IDers

About 'The lack of cooperation between EDer and IDer', it was thought necessary to investigate the actual situation, and to set appropriate 'Cross examination of the design by EDers and IDers'. Because unlimited and frequent cross examination may waste time.

IX. Investigation of the Actual Situation

To investigate the actual situation communication logs between EDers and IDers are requested for another project of a new model that started later. The logs were analyzed at the time when logs up to the Prototype Evaluation Phase were available. And a period when the communication is interrupted was identified.

The analysis reveled that the period when the communication does not take place corresponds to the "Detailed Design Phase" that is shown in the Fig4. In that phase EDers concentrate on realization of functions, considering ID just as restrictions. On the other hand, IDers are finishing the exterior appearance without considering the functions. As they are concentrating complete the exterior design, interior is just considered as restrictions.



Source: sugiyama[1]

Fig. 4 Collaboration type development process between ED and ID

X. Solutions

From the above research result, the cross examination of the design by EDers and IDers in detailed design phase were found effective to prevent the problems. However this period is important for both of the parties to concentrate on their tasks, as described above, frequent cross examination may waste time.

Therefore this research examined the tasks of the both parties in this period to clarify the points to be checked and to find out the appropriate timing for the cross check. Review of the tasks was conducted with 2 ED managers who experienced designing of office equipment such as document scanner, photo copier and Laser Beam Printer, 2 ID managers who were involved not only with office equipment but also with medical equipment, cameras and industrial equipment, and the author himself in the form of discussion. The object product is limited to office equipment and description of the task is generalized to make it applicable to office equipment in general. The result is shown as follows.

Task of ED in Detailed Design Phase

(1) Draw a visible outline

Draw a shape (measurement as restrictions) based on the basic design

(2) Lay out basic parts in detail

Lay out image scanning or image forming process parts/units, control print circuit board, power supply and so on

(3-A) Lay out functional parts

Lay out motor and vehicle (gear, pulley, belt, and so on)

(3-B) Realize maintenance functions

Enable user to recover paper jam, replace consumption articles, and clean up inside, and so on

(3-C) Wire harnessing

Lay out other electrical parts such as sensors and connect parts electrically by cables

(4) Lay out exterior covers

Decide the shape of exterior part and separate it into plural parts tentatively in order to enable to install them in mass production

(5) Lay out operation panel parts

Decide means to install operation button, panel and electrical inside parts

(6) Design parts in detail

Fix on shapes for every each part finally

TASK OF ED IN DETAILED DESIGN PHASE

(1) Draw exterior outlook

Draw exterior outlook based the basic design

(2) Make a simple mock-up

Make simple mock-ups and check their aesthetics, impression of volume and so on

(3-A) Modyfy the exterior

Modify exterior shapes and proportion

(3-B) Modify parting lines between covers

Modify parting lines between covers in order to make improvements on exterior outlook with techniques such as emphasizing and obscuring

(3-C) Modify a partial design

Modify exterior outlook of peripheral parts such as paper feeding tray and paper ejection tray in order to improve their aesthetics and operability

(4) Lay out operation panel parts

Optimize shape of operation button, panel, and printings in order to improve operability

(5) Optimize operation panel for maintenance

Optimize shape and layout of parts for maintenance operation such as paper jam recovery, replacing consumption articles, and inside cleaning in order to improve operability

Cooperative design with ED and ID was created as a work flow of Fig 5 and the right timing for cross check (DR3-1, 3-2, 3-3) and the view point (the right side of the chart) were set. Items to check specific to EDer and IDer for respective tasks were also added to the chart on the basis of the problems extracted in the previous section (the left side of the chart).

A list of “The items to check” for each DRs was created on the base of the ID attributes extracted by Sugiyama et al.[11] and by reflecting the discovered problems (by the research) in the integration process between ED and ID.

Followings are the specific timing for cross check.

DR3-1: At this stage construction is fixed and able to clearly see how the exterior cover is divided and see the relative position to the interior components. Maintenance area is hard to change at the later stages.

DR3-2: At this stage final review is required in terms of universal accessibility and usability.

DR3-3: Final review is mandatory prior to prototyping.

XI. The General Effectiveness of Suggestions

As the research was made on cases of document scanners in one company, 2 EDers and 2 IDers listed below reviewed the general effectiveness of suggestions this study brought.

Reviewer A: Eder of a different type of business equipment from document scanner

Reviewer B: Eder of another computer terminal equipment

Reviewer C: IDer belonged to a automotive industry.

Reviewer D: IDer in a design office that designs variable type of product (business equipment, medical equipment, etc.)

As a result, we obtained following opinions from each reviewer.

Reviewer A: The contents listed in this article are almost facts in many cases, and it is thought that DR added by this study is effective as measures of the prime cause. However the lack of communication tends to have a minor role among the causes of the problems when EDer knows ID well (or in the reverse case). Accordingly, measures are not applicable in all cases.

Reviewer B: There are no empirical proofs, but there are some lack of communication between EDers and IDers, and some disorders caused by the lack.

Reviewer C: In the automotive industry, the lack of communications between EDer and IDer in detailed design phase is recognized as the problem by the same reason. So weekly regular meeting has started several years ago. But DR’s determined timing and items to check proposed in this study seem more effective and efficient.

Reviewer D: The disorders caused by lack of communications between EDer and IDer in detailed design phase are recognized. The frequency of the occurrence of disorders depends on designer’s personalities; however, there is a certain expectation that performance of the DR added by this study reduces disorders without depending on designer’s personalities.

Because affirmative opinions were obtained as above, the solutions of this study was put in practice to different development of products, and verified effects.

TABLE I shows comparison list between before measures and after measures. Following effects were verified by statistical test specifically the difference test of the fraction defective.

- Number of problems decreased.
- The problems of “Not suitable for mass production” that requires long time to fix decreased.
- The problems of “Lack of impression as compact”, “Inadequate functions” and “Parts interference” decreased.
- The problems detected in “Prototype Evaluation Phase” and “Mass Production Design Phase” decreased.

In addition, accomplishment of quality at early stage was confirmed with statistical test specifically the difference test of the distribution, showing statistically significant decrease of problems in “Prototype Evaluation Phase” and “Mass Production Design Phase”

The number of “Not good for operation” increased but it is because the number of components is larger, and no fatal problem occurred. These are only the fine adjustments to improve quality as much as possible. These are problems that are possible to notice only after producing prototypes. The progress of the simulation technology such as the virtual reality using three-dimensional data that enables to check before producing prototypes is waited for. In addition, to confirm the design at its earlier stage, producing partial trial models by rapid prototyping technologies would be effective.

TABLE I
NUMBER OF PROBLEMS

		Before measures	After measures
Number of components (except electric component)		281	631
Number of problems		31	27
Type of problem	Not suitable for mass production	7	2
	Not good for operation	6	13
	Not good for safety operation	5	4
	Not good aesthetically	5	7
	Lack of impression as compact	3	1
	Inadequate functions	3	0
	Parts interference	2	0
Phase of integration process	Basic Design Phase	3	3
	Detailed Design Phase	2	10
	Prototype Evaluation Phase	18	10
	Mass Production Design Phase	8	4

XII. CONCLUSION

This research identified and analyzed the problems come up in the process of integration of ED and ID, found the causes of them, and propose the solutions for them. The lack of cooperation in the detailed design phase was revealed as the cause of problems and improvements in integration process was proposed. Solutions were put in practice and verified. Improvement is necessary with the increased cases.

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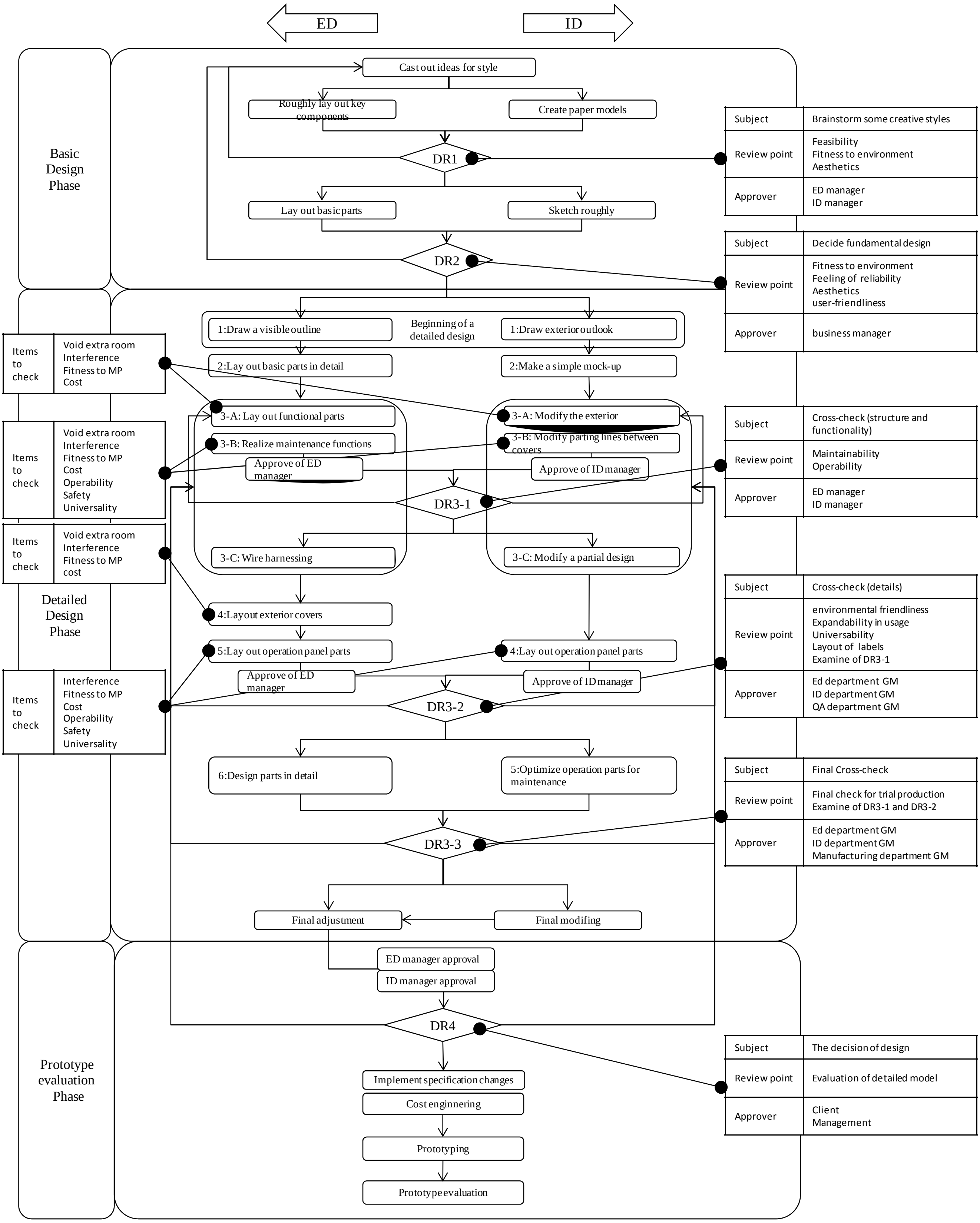

Source: sugiyama[1]

Fig. 5 Created work flow of collaborative design with ED and ID