Employing a Decision Support System (DSS) application system to modify a non-standard wall-mounting electrical panel using a 3D CAD modelling

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Abstract
Flexibility in the design process becomes an absolute necessity in a smart factory in the era of industrial manufacturing 4.0. CAD technology with a 3D modeling capability serves as a backbone in the design process in a manufacturing industry. Here, iLogic serving as an add-on of Inventor software will be combined with a Decision Support System (DSS) to build a DSS application system, namely "Panel Auto System". This system will help an engineer modify a 3D model wall-mounting panel to fulfill a non-standard order from his or her customers. This 3D-model database from various parts of the wall-mounting panel is generated from the 3D modeling. Then, by employing the if/then/else rules in the iLogic, the system can modify a 3D model wall-mounting panel data standard and serves as a geometric 3D model based on the customer's order. The system works well and has been validated. The efficiency of the modeling process using the "Panel Auto System" increases its time efficiency up to 97,6 % compared to a manual process. Therefore, this system can increase the engineer's productivity in the design of an in-wall mounting panel, and the customers can get the order of their 3D model faster.

INTRODUCTION

Commonly practiced in the manufacturing industry, the modeling process of both sketch-based 2D and sketch-based 3D modeling usually employs a manual and a digital technique such as CAD. In this modern era, the 3D model has grown rapidly and can be learned. Moreover, it also serves as a media aiding various human activities. For instance, we use virtual engineering models to improve our spatial skills and gain a better knowledge of 3D contours [1] in a manufacturing process.

Currently, CAD/CAM also serves as one of the backbone technologies in industry 4.0 pillars since it specifically serves as the input data for additive manufacturing, simulation, and augmented reality. Augmented reality is also used to simulate a manufacturing process in a computer, known as virtual manufacturing [2]. Virtual manufacturing has several benefits such as reducing material waste while lowering costs and lowering the risk of poor design, too [3].

Virtual manufacturing is a computer system capable of producing the same information on the structure, state, and behavior of a manufacturing system as we see in the real manufacturing system; moreover, it is also capable of reducing material waste while lowering costs and lowering risk because of the design and manufacturing process planning errors [4]. Industry 4.0 in an industrial activity is realized through a "smart manufacturing" -- a manufacturing system that can meet and exceed the challenges of today's manufacturing systems by cyber-physical system (CPS) implementation among the machines in a factory. It is capable of eliminating boundaries and limits by shortening the product manufacturing cycle and adjusting the product manufacturing through a competitive method [5][6].

To generate a work item, a manufacturing process typically uses several tools particularly for machining. 3D printing is a kind of technology that can help in a manufacturing process [7]. It is an evolution in the manufacturing sectorial lines gradually displaying its most recent innovations with each line through continuous improvement and diverse best practices [8].

CAD technology is also implemented in the design and manufacturing of an electrical component. An electrical panel is a cube-shaped object of various sizes with its side containing a power gauge and limiter and an electrical panel containing equipment for the distribution of electrical power or connecting equipment [8]. An electrical panel also serves to handle the current or flow of wild electricity with a grounding in order that it can be secured and will not give any harms [9].

The 3D CAD is beneficial in the designing of an electrical panel. Many faults and losses occur due to an electrical installation and electrical setting error [10]. If the dimensions of an electrical panel do not comply with the standard, they may negatively impact on the operational costs due to waste of electricity. Moreover, it is possible for the factory to undergo breakdown due to an electrical installation error or a non-standardized electrical panel. Using a standard electrical panel also provides us some benefits in that it makes us easier to maintain the electrical installation maintenance system [11] and to keep the machines at the factory from being damaged due to an unstable power supply or a frequent breakdown.

The size of the electrical panel increases proportionally to the increasing demand for a changing electrical power due to various aspects such as the number of the electrical components, the size of the room, and the factory standard to which the electrical panel will be installed. The need for the size of an outside-the-standard panel which still guarantees safety requires flexibility in the design process of an electrical panel. It requires a flexible system which does not extend the design time [12].

A mechanical and an electrical panel usually have an IP code on the device nameplate to determine the specifications of the panel. IP code (Ingress Protection) is a kind of protection for an electrical device inside the work system of a protection panel or device, and it represents resistance to the direct contact or penetration of an electrical device by a foreign material such as water or dust [13]. Currently, the design of an electrical panel is made by complying with the IP standards using CAD - Inventor software. Moreover, the database is available. However, the customer sometimes asks for a design with a slightly different size from the standard size, so the designer has to make several modifications resulting in a longer time consumed and prolonging the manufacturing time. Hence, this situation creates a problem, and the solution to this problem is creating an application program compatible with CAD - Inventor software. The application program is a 3D modeling supported by Decision Support System (DSS). A designer can use this application program to help him or her decide on which type of panel design will meet his or her customers' requests and his or her minimum modification efforts [13]. Combined with the CAD-I inventor software, this application program serves to shorten the design modification time. This application serves to make a component and an assembly on an electrical panel to be mounted on the wall. The designer can later use the application by filling out the forms provided to modify the required electrical panel, and the 3D modeling process will automatically be done, making it faster and more efficient.

Decision Support System (DSS) is an information system designed to help businesses store, manage, analyze. Eventually, it helps a manager to make his or her decision [14]. DSS employs a summary of information, exclusions, patterns, and trends using an analysis model. DSS helps a manager in his or her decision-making process. However, it does not have to make a decision by itself. There are two types of decision-making processes: programmatic and non-programmed. A decision-maker collects useful information from raw data, documents, personal knowledge, and business models to identify and solve a problem and make a decision.

The major components of a DSS include a problem solver, system function, and development process [15], and they are built with a thorough data analysis, an analytical and statistical research, an evaluation of alternatives, and evaluation of decision optimization criteria, all of which may necessarily be significant and may require an exhaustive investigation given that a DSS comprises four primary components, namely a user interface, data, model, and knowledge base [16].

Then, from the generated DSS system, the conceptual design will be selected from the if-then-else rules from iLogic. ILogic technology enables an engineer to develop a library of standard and standard products in a CAD program in order to get a quick rebuild of the geometry of a product based on a CAD program calculation as soon as a specification in the source data is changed [17].

The iLogic programming language, which is comparable to a scripting language, is utilized when If-then-else rules, select-case decision trees, and loops are all common constructs. Sub functions and sub procedures can be utilized in the code, and variables can be used both globally and locally. For the sake of practicality, in every modeling scenario, the Inventor has a snipped library [18]. The program design will be based on the conceptual model having been selected from the iLogic rule result. In most cases, CAD software will translate the conceptual design into a 3D model [19]. This system is part of a new generation of a computer-aided design (CAD) system actively promoting a design decision-making environment and a problem-based learning strategy. A meaningful internal object-based representation of the 3D model designed within its context environment is the most important of these [20].

MATERIAL AND METHODS
Preparation
The system should take several components to build a DSS. They are as follows: Database part panel, Assembly panel 3D, Parameter, Form, iLogic rules, Computers with specifications required to discharge the inventor.

Steps taken to build building a DSS are as follows.
1. First, 3D parts made on the inventor standard to be used as the aim serves to change the panel size on the system,
2. Then, all parts are mated into one whole assembly with the rules to be used.
3. Make the parameters to be used to build a form having been divided based on the type of parameters to be used.
4. Make the global form from the plan previously designed.
5. Make the rules with ilogic language employing the parameters.
6. Run the program to avoid any errors. Afterwards, make a simulation to check whether the program is applicable, so the system can be properly run.
7. Finally, store all of the files in a file folder for a future use.

DSS Configuration
Figure 1 shows a DSS configuration divided into 3 (three) parts, namely: data, model, and knowledge. Knowledge in this system is obtained from the system designer's understanding. He or she is designer must understand the points written in Figure 1 to build the DSS system in question. In regards to the rule base, the logic system points explaining the if-then-else decision. Then, they are processed

into a unified system to be later processed in the user interface to be employed as a conclusion or decision that will build the 3D modeling of the desired wall-mounting electrical panel.

Database Wallmounting Part
Figure 2 shows parts of the data used to build a panel in the DSS program.

There are eight components of the panel employed to build the DSS program, namely:
1. Body. It is a part of the mainframe on the panel serving as the base then attached to the mounting and other electrical components.
2. Cover. It is a part covering the main outline located on the top and the bottom of the panel combined into one with the body to form a panel box.
3. Door. It is a main part serving as the front cover paired with the hinges, locks, and handles, so it can be opened and closed.
4. Ear Mount or panel ear. It is a component used to support the panel in order that the panel can be placed on the wall.
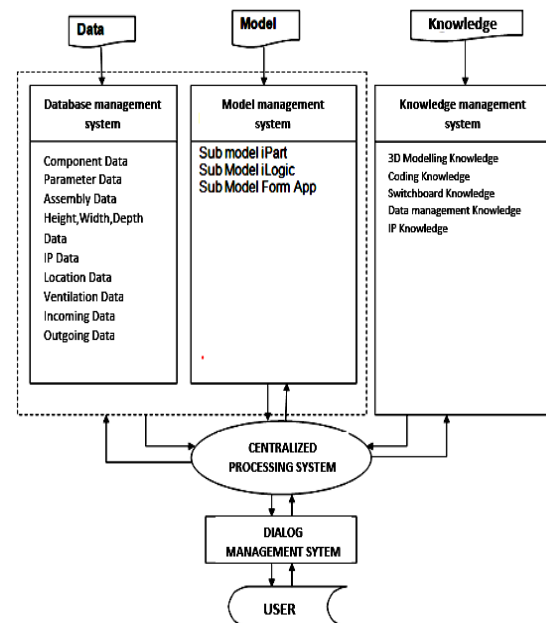

Figure 1. Decision Support System (DSS) configuration

Figure 2. Database Part

5. Mounting. It is a tray-like component used to place an electrical component on the panel in the box.
6. Incoming/Outgoing plate. It is a plate cover for the incoming and outgoing cable holes on the panel installed above or below the panel depending on the desired specification.
7. Canopy. It is a part of the roof often called a panel cap used in an outdoor-type panel to protect the top from the rain, so the rain will not get into the panel.
8. Rubber. It is a protective component employed if the panel specification requires an IP_B to avoid any fluid when tested.

Database Parameter

The parameters used are the data having been inputted as a value or a text in which it can be added, delimited, or duplicated as a rule to be used as shown in Figure 3.

The parameters used in this system are:
1. Dimension parameters. They are data on the size dimensions used to set the height, width, depth, and size required by the system.
2. Boolean parameters. They are parameters used in a Boolean operation in the modeling of a CAD. The parameters of a Boolean operation to be used in the building of a 3D panel model are obtained by specifying true-or-false based options provided by the system.
3. Decimal parameters. They are numerical data forms used by the system to determine the IP_A and IP_B.
4. Description parameters. They are data in the form of a text in the information form of the system used to fill in the location, incoming, and outgoing forms.
5. Merged parameters in the data form to be combined into a merged data form, so they can be created and edited by the Inventor software.
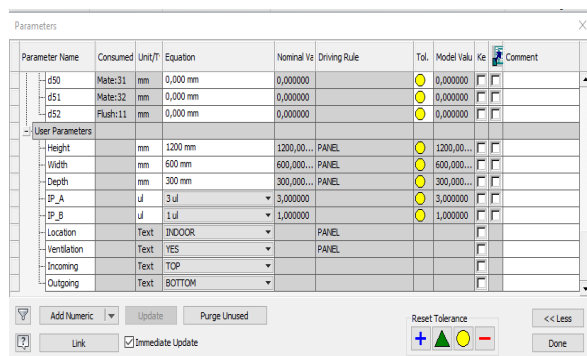

Figure 3. System parameter

iLogic System

The Decision Support System will be built by employing the If and Else rules. Figure 4 shows the iLogic Flowchart elaborating the description of the program development.
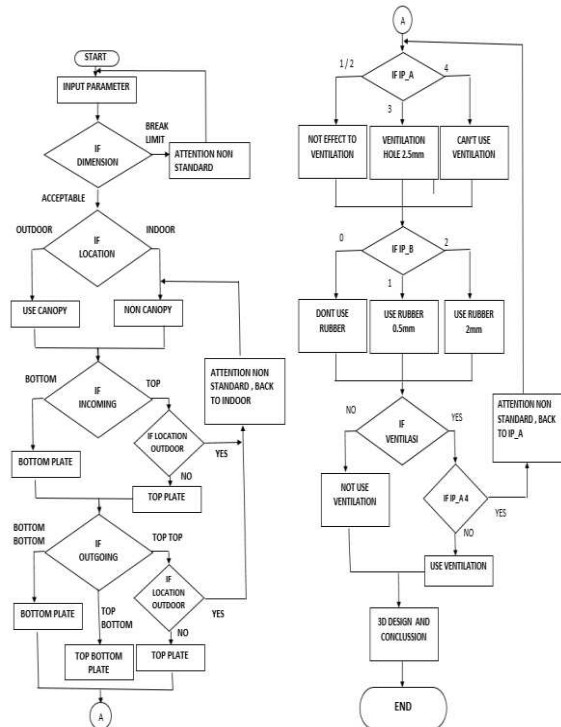

Figure 4. iLogic Flowchart.

The program will be started by entering the data input of the height dimension of the 3D model panel with the options as follows:

input in the form of size data (mm)
If High < 500 then High = 500
If High > 1200 then High = 1200

It means that the height of a wall-mounting panel is limited to sizes ranging from 500 mm to 1200 mm following the size of a panel already existing in the manufacturing standard. The next step is to input the width dimension option as mentioned below.

If Width < 300 then Width = 300
If Width > 900 then Width = 900

The statement above means that the width of a wall-mounting, 3D model panel is limited to sizes ranging from 300 mm to 900 mm following the size of a panel already existing in the manufacturing standard. Afterwards, the next step is to input the depth dimension option.

If Depth < 200 then Depth = 200
If Depth > 400 then Depth 400

The statement above means that the depth of a wall-mounting panel is limited to sizes ranging from 200 mm to 400 mm following the size of a panel already existing in the manufacturing

standard. Then, the next step is to select an indoor or outdoor form option.

> *Input in the form of Description "INDOOR" or "OUTDOOR".*
> *If Location = "OUTDOOR" Then*
> *Canopy = True*
> *Else Canopy = False*

If the input value is at location "OUTDOOR", then the Part Canopy will be active. Meanwhile, if the value is other than that value, the canopy will be inactive.

> *If Location = "OUTDOOR" and (Incoming = "TOP" And Outgoing = "TOP") Then*
> *Canopy = False*
> *Location = "INDOOR"*

It is a special or additional decision if the location value is "OUTDOOR", and the incoming and outgoing value is "TOP" since the canopy will be deactivated and will return to the "INDOOR" input value.

> *Input in the form of information "TOP" or "BOTTOM" in each column.*
> *If Incoming = "TOP" And Outgoing = "TOP" Then*
> *TOP plate = True*
> *BOTTOM plate = False*
> *Else*
> *BOTTOM plate = True*

The statement above means that when the incoming and outgoing input values are the same as "TOP", then the cover plate and the hole on the top will be active. Meanwhile, the plate and the hole on the bottom will be inactive if the input values are other than "TOP".

> *If Incoming = "BOTTOM" and Outgoing = "BOTTOM" Then*
> *TOP plate = False*
> *BOTTOM plate = True*
> *Else*
> *TOP plate = True*

The statement above means that if the incoming and outgoing input values are the same as "BOTTOM", then the cover plate and the hole on the bottom will be active. Meanwhile, the plate and the hole on the bottom will be inactive if the input values are other than "BOTTOM". The next process is selecting the number of IP_A. The number of the IP_A selected will determine the diameter of the ventilation holes.

> *Input is Decimal [1,2,3,4] = 4 inputs.*
> *(IP A is limited to IP 4X)*
> *If IP_A = 1 or 2 Then Ventilation Hole = 5 mm*
> *If IP_A = 3 Then Ventilation Hole =2.5 mm*
> *If IP_A = 4 Then Ventilation Hole = False*

Next, the statement below is used to select the numeric of IP_B. The numeric of IP_B

determines the type of rubber and its thickness to be used.

> *Input is Decimal [0,1,2] = 3 inputs.*
> *(IP B is limited to IP X2)*
> *If IP_B = 0 Then Rubber = False*
> *If IP_B = 1 Then Rubber =0.5 mm*
> *If IP_B = 2 Then Rubber = 2 mm*

Both IP_A and IP_B are in accordance with the existing reference of the IP standards. The next step is to input the Boolean data form.

> *Input in the Boolean data form (Yes/no)*
> *If Ventilation = "NO" Then Feature Ventilation = False*
> *Else Then Feature Ventilation = True*

If the value of the ventilation parameter is "NO", then the ventilation hole feature will be disabled which means that there are no ventilations. If the value is other than that value, the feature will be active.

Next, the logic is combined and realized in the iLogic program provided by the Inventor software and uses the parameters having been prepared by employing the add rules, so a coding program will be generated as shown in Figure 5.
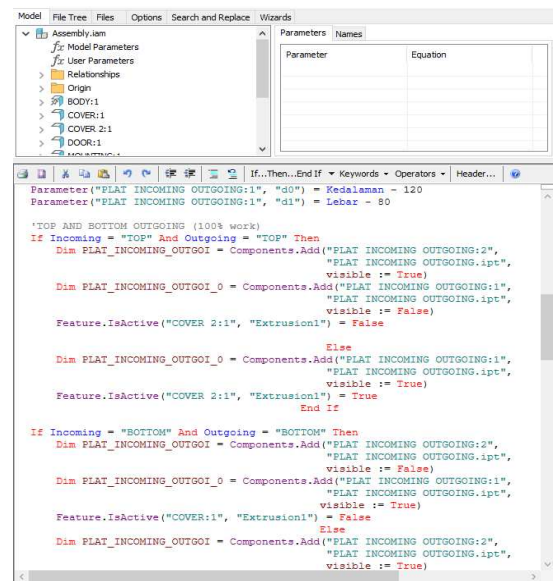

Figure 5. iLogic system

RESULTS AND DISCUSSION
DSS Panel Auto

DSS system is started by opening the assembly design with the ilogic system. First, displayed from the system, the assembly base file having been created and clicks on the login button on the form is simply opened by the user in order to run the systems as shown in Figure 6.

Then, as shown in Figure 7, a form will appear, and the user must fill in the form with the name of the designer and the project serving as the information so as to log in to the system.
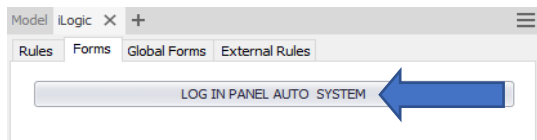
Figure 6. iLogic system

Figure 7. Log in panel

Figure 8. iLogic system

The user should open the application button and will be displayed as shown in Figure 8. Then, the user must fill in the existing parameter form with the specifications of the switchboard pursuant to the customers' needs. Each of the forms contains parameters as follows:

1. Height: It is the height dimension of the panel that the user desires.
2. Width: It is the width dimension of the panel that the user desires.
3. Depth: It is the depth dimension of the panel that the user desires.
4. IP_A: It is the initial IP number used to protect the system from any from Solid objects.
5. IP_B: It is the initial IP number used to protect the system from any fluid objects.

6. Location: It is the location of where the panel will be placed.
7. Ventilation: It is the use of holes employed to circulate the air.
8. Incoming: It is the course of the location of the cable entering the panel.
9. Outgoing: It is the course of the location of the cable going out of the panel.

After filling in the form, the user must click the apply button to generate the program. Then, the program will display some warning messages and descriptions based on the filled-out form. Finally, the conclusion of the DSS process will appear as shown in Figure 9.

Figure 10 shows us that the standard design of the panel on the left will change to a new design on the right after the data inputs are filled out to the form in the system. The panel changes its size based on the input and adds some additional accessories in the forms of a hole and canopy with the right size in accordance with the specifications of the IP, the ventilation, and the location of the panel.
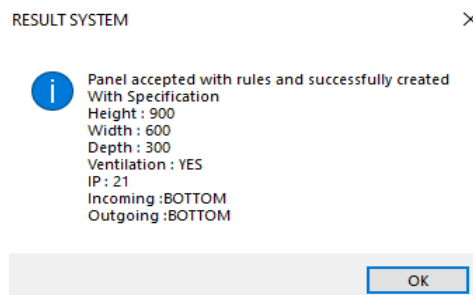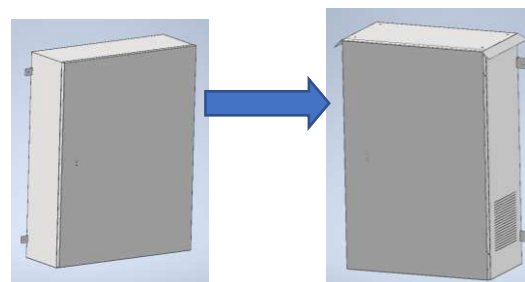

Figure 9. Result system

Figure 10. Example Result.

Validation

The program must first be validated before it is used by the user. Validation is a process ensuring that the geometric 3D model resulting from the design simulation process using the DSS is in accordance with the expected target. The validation process is carried out by comparing 10 samples of the modified simulation panel designs at random to the standard panel design rules. If there is an incompatibility in the results of the 3D model, then a warning message will appear on the monitor, so the design can be

readjusted. Table 1 shows the results of the validation. The simulation results with an OK status as shown in Table 1 shows us the DSS runs based on the desired rules in its programming. Moreover, there are no errors or damage to the resulting 3D model. It means that the system is valid and can serve as a tool for the designer or the system user to work more efficiently.

Table 1. Validation Result

No	Height (mm)	Width (mm)	Depth (mm)	Location	Incoming	Outgoing	IP_A	IP_B	Ventilation	Status
1	1200	900	400	Indoor	Top	Top	4	2	No	Ok
2	1100	800	300	Outdoor	Bottom	Bottom	4	2	No	Ok
3	1000	700	400	Indoor	Top	Top	3	1	Yes	Ok
4	900	600	300	Outdoor	Bottom	Bottom	3	1	Yes	Ok
5	800	900	400	Indoor	Top	Top	2	1	No	Ok
6	700	800	300	Outdoor	Bottom	Bottom	2	1	Yes	Ok
7	600	700	400	Indoor	Bottom	Top	2	0	No	Ok
8	700	500	300	Outdoor	Bottom	Bottom	1	0	Yes	Ok
9	600	400	400	Indoor	Bottom	Top	1	0	No	Ok
10	500	300	300	Outdoor	Bottom	Bottom	1	0	Yes	Ok

Simulation Time

The system is equipped with a formula to calculate the time required to modify the standard panel components using CAD software having been equipped with the DSS program on iLogic. Then, its results will be compared to the time it takes to modify the standard 3D panel components in common CAD software done manually. In a manual 3D CAD modeling process, the designer manually edits the bend sizes, the positions of the holes, and the assembly distances, thus consuming much more time. In a CAD software having been equipped with a DSS on iLogic, the modification process is carried out by obtaining the 3D model data input from the database. Then, the program will process it by using the existing knowledge in the system. The modeling time of components 1 - 10 as shown in Table 1 is manually calculated. Then, it is compared to the modeling time employing iLogic with DSS to find out how much time it can save. Table 2 shows the results and the comparison of the two methods.

Trimming time

Based on the results of the experiments, it is found out that the average time required by the manual 3D panel model modification process is 1163 (s), while the average time required by the 3D panel model modification process using a CAD equipped with DSS on iLogic is 27 (s).

The results of the time of the experiment can be obtained through calculations, where Average from manual time is 1163 s and Average from system time is 27 s. Next, the average time difference between the modification of the 3D panel model using CAD equipped with the system and the modification of the 3D panel model using a manual CAD will be calculated.

Table 2. Simulation time

No.	Manual Time (s)	System Time (s)
1	1143	26
2	1332	31
3	1106	25
4	1432	24
5	1032	26
6	1265	30
7	1076	33
8	1153	26
9	996	23
10	1094	28
Average	1162.9 (1163)	27.2 (27)

Then, the results of the time difference will be divided with the average time of the modification using a CAD manually and multiplied by 100% to find out the percentage of time that can be saved. The percentage is 97.6%.

Finally, the validation proses shows us that the system is valid to use, the design process can run smoothly without any constraints, and it has an attractive, user-friendly interface that can easily and effectively be operated even by a newbie designer.

CONCLUSION

The validation process shows us that the system is valid to use. The design process can run smoothly without any barriers. Moreover, it has an attractive interface that can easily and effectively be operated even by a newbie designer. The system can save a lot of time required to modify the 3D part panel using a CAD manually from 1163 seconds to 27 seconds if the CAD is equipped with DSS on iLogic. The designer only needs 1 file assembly with some additional files obtained from the DSS program should there be any new updates. In fact, a newbie designer can easily operate this system by simply filling in the form having previously been made.

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