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CLASSIFICATION AND FACTORS OF HUMAN ERROR IN THE CREATION OF MANUFACTURING DRAWINGS AND MATERIALS LISTS.

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Resumen: En cualquier tipo de proceso siempre existe la posibilidad de errores durante su desarrollo. La tarea analizada en este caso es una de las tareas del proceso de diseño de herramientas para el soldado de componentes en tablillas electrónicas que consiste en generar planos y listas de materiales de los diseños realizados. En esta actividad se reportan frecuentemente casos donde errores como información errónea o incompleta ocasiona diversos atrasos, cuellos de botella, retrabajo, desperdicios que representan costos e ineficiencia. El objetivo de este trabajo es utilizar técnicas para analizar la confiabilidad humana y proponer recomendaciones concretas para reducir la posibilidad de errores humanos. El estudio se llevó a cabo con herramientas de ergonomía cognitiva como el Análisis Jerárquico de Tareas (HTA) y después con el método de Enfoque Sistemático de Reducción y Predicción de Errores Humanos (Systematic Human Error Reduction and Prediction Approach SHERPA). Se utilizó una muestra por conveniencia de ocho miembros del equipo de diseño en una empresa de manufactura de herramientas para procesos de soldado de componentes en tablillas electrónicas en Ciudad Juárez, Chihuahua, México. El HTA se desglosó en la tarea principal y subtareas que la integran obteniendo información detallada de la actividad de cada una de ellas, procediendo después con la clasificación y asociación de modos de error en cada una el método SHERPA determinando las consecuencias asociadas a cada modo de error. La tarea 4 sobre generar planos y listas de materiales de diseño, resultó ser la tarea más extensa en el proceso con 17 subtareas y estas subtareas con actividades que demandan altos niveles de atención, son repetitivas y se ejecutan con urgencia por lo que es vulnerable a errores. Clasificando y asociando los modos de error de cada subtarea con las taxonomías de SHERPA, se identificaron consecuencias, posibilidades y criticidad de estos modos de error. Un total de 26 errores humanos, de los cuales 25 fueron de acción (96.15%) y 1 de selección (3.84%). Las taxonomías identificadas con mayor presencia fueron “actividad omitida” con 13, seguido de “actividad incompleta” con 9, “actividad demasiado corta o larga” 1, “poca o mucha cantidad de actividades” 1 y “selección incorrecta” 1. La criticidad y probabilidad, en conjunto definen un nivel de riesgo de ocurrencia del error, el nivel encontrado en las subtareas analizadas fue alto en 18 de ellas (69.23%) y mediano en 8 de ellas (30.77%). La repetibilidad de las actividades en cada proyecto tomando en cuenta que se realizan de 2 a 3 diarios por diseñador, hace que sea una tarea extensa y vulnerable a errores por condiciones, por lo que es recomendable realizar cambios en esta actividad.

Palabras Clave: Error humano, Análisis Jerárquico de Tareas, SHERPA.

Relevancia para la ergonomía: Esta investigación contribuye al análisis de tareas propias del diseño para la manufactura utilizando herramientas de Ergonomía Cognitiva, ya que el análisis del error humano es escaso en procesos de diseño. En este caso, se estudió la tarea de realizar planos de piezas o elementos diseñados y listas de materiales para cada proyecto en el departamento de diseño de una empresa local y los errores humanos que se presentan durante la realización de la actividad en el proceso de diseño. Esta tarea es una de las más frecuentemente realizada en los procesos de diseño para manufactura y las características de la tarea y las condiciones presentes en las industrias fomentan situaciones en las que el error humano es frecuente. Debido a una extensa realización de actividades y a un proceso largo en algunas subtareas, el individuo se ve afectado al tener que mantener altos niveles de atención, que influyen en el procesamiento de información y la memoria, estos sistemas cognitivos se van degradando, propiciando errores de acción, omisiones y dando como resultado el error humano con efectos como frustración, esfuerzo y carga mental en el ser humano. En aquellos cuya criticidad es alta, así como la alta probabilidad de ocurrencia propicia desperdicios, defectos y mala calidad en el subproducto y producto final generando altos costos en la compañía.

Abstract: In any process, there is always the possibility of errors during its development. The task analyzed in this case is one of the tasks of the tool design process for the soldering of components on electronic boards, which consists of generating drawings and bills of materials of the designs made. In this activity, cases are frequently reported where errors such as erroneous or incomplete information cause delays, bottlenecks, rework, and waste that represent costs and inefficiency. The objective of this work is to use techniques to analyze human reliability and propose concrete recommendations to reduce the possibility of human errors. The study was carried out with cognitive ergonomics tools such as Hierarchical Task Analysis (HTA) and then with the Systematic Human Error Reduction and Prediction Approach (SHERPA) method. A convenience sample of eight design team members was used in a tooling manufacturing company for electronic board component soldering processes in Ciudad Juarez, Chihuahua, Mexico. The HTA was broken down into the main task and subtasks that integrate it, obtaining detailed information of the activity of each one of them, proceeding later with the classification and association of error modes in each one using the SHERPA method, determining the consequences associated with each error mode. Task 4 generating drawings and designing BOMs, turned out to be the most extensive task in the process with 17 subtasks and these subtasks with activities that demand high levels of attention, are repetitive, and are executed with urgency so it is vulnerable to errors. By classifying and associating the error modes of each subtask with the SHERPA taxonomies, the consequences, possibilities, and criticality of these error modes were identified. A total of 26 human errors, of which 25 were action errors (96.15%) and 1 selection error (3.84%). The taxonomies identified with the highest presence were “omitted activity” with 13, followed by “incomplete activity” with 9, “activity too short or long” with 1, “too few or too many activities” with 1, and “incorrect selection” 1. The criticality and probability, together define a level of risk of occurrence of the error, the level found in the subtasks analyzed was high in 18 of them (69.23%) and medium in 8 of them (30.77%). The repeatability of the activities in each project, taking into account that 2 to 3 are performed daily by the designer, makes it an extensive task and vulnerable to errors due to conditions, so it is advisable to make changes to this activity.

Keywords: Human error, Hierarchical Task Analysis, SHERPA.

Relevance to Ergonomics: This investigation contributes to the analysis of tasks within design for manufacturing by utilizing Cognitive Ergonomics tools, as the study of human error in design processes is scarce. In this case, the task of creating drawings for designed parts or components and preparing material lists for each project was studied within the design department of a local company, along with the human errors that occur during the execution of these activities in the design process. This task is one of the most frequently performed in design for manufacturing processes, and the characteristics of the task, along with the conditions present in industries, create situations where human error is common. Due to the extensive nature of the activities and the prolonged process involved in some subtasks, individuals are affected by having to maintain high levels of attention, which influences information processing and memory. These cognitive systems degrade over time, leading to action errors, and omissions, and resulting in human error with effects such as frustration, effort, and mental workload. In cases where the criticality is high and the probability of occurrence is also high, this leads to waste, defects, and poor quality in the subproduct and final product, generating high costs for the company.

1.- INTRODUCTION

A work team of the design department of a manufacturing company in Ciudad Juarez Chihuahua Mexico is made up of engineers specialized in mechanical design and manufacturing for the development of support tools to process electronic boards through various assembly and soldering processes. In this company, in the internal process control records shown in Figure 1, it is observed that the frequency of errors where the information is erroneous, incomplete, or not updated in the manufacturing drawings is the highest in the elaboration of the parts designed by the engineers of the department. The consequences generated by these errors or omissions of information range from bottlenecks in the flow of the manufacturing process, rework of parts, time extension, and loss of materials, among others, which results in considerable costs and economic losses for the company that can amount to several thousand U.S. dollars. In addition, the performance of the task under adverse and stressful conditions (Salas-Arias et al., 2018) propitiates in employees high levels of mental load due to attention, frustration, and mental and physical effort due to the limited time required to execute it. It is defined that human error is the incorrect or inappropriate execution of an action, particularly the failure to perform an activity (Chamby, 2018). The study of human error and the reliability of their actions is a complex subject, in which it is convenient to keep in mind that the individual's actions are always due to and from a diverse number of variables that involve personal, organizational, situational and/or environmental issues, which usually make it impossible to definitively determine the causes (Báez et al., 2013). To study human error there are data collection techniques that are used to collect concrete information about the activities performed in complex systems, and task analysis methods describe and represent them. Among the best-known and most widely used task analysis methods is Hierarchical Task Analysis (HTA) (Phipps et al., 2011) (Annett & Duncan, 1967). Navas de Maya et al., (2022) mention that this analysis has the peculiarity of presenting the tasks in a strict hierarchical structure, the main objectives (tasks) are represented at the top, while the secondary objectives (subtasks) are presented at the bottom. Thus, the HTA process is simplistic, it involves collecting data about the task or system under analysis through multiple techniques such as observation, experience, questionnaires, interviews, or documentation review among others, and then uses the data to decompose and describe the objectives and sub-objectives involved, (Stanton et al., 2005). Generally, any human factors analysis requires some form of task analysis, whether it is usability evaluation, error identification, or performance evaluation (Stanton et al., 2005; Stanton, 2006). The task description provided by these task analysis methods is often used as a basis for other analysis methods such as Systematic Human Error Prediction and Analysis SHERPA (Ghasemi et al., 2013) (American Nuclear Society. Human Factors Division. et al., 1986). This technique by taxonomies is used to qualitatively and quantitatively evaluate human reliability and develop concrete recommendations to reduce the probability of human errors, especially in terms of procedures, personnel training, and equipment design (Torres-Medina, 2020).

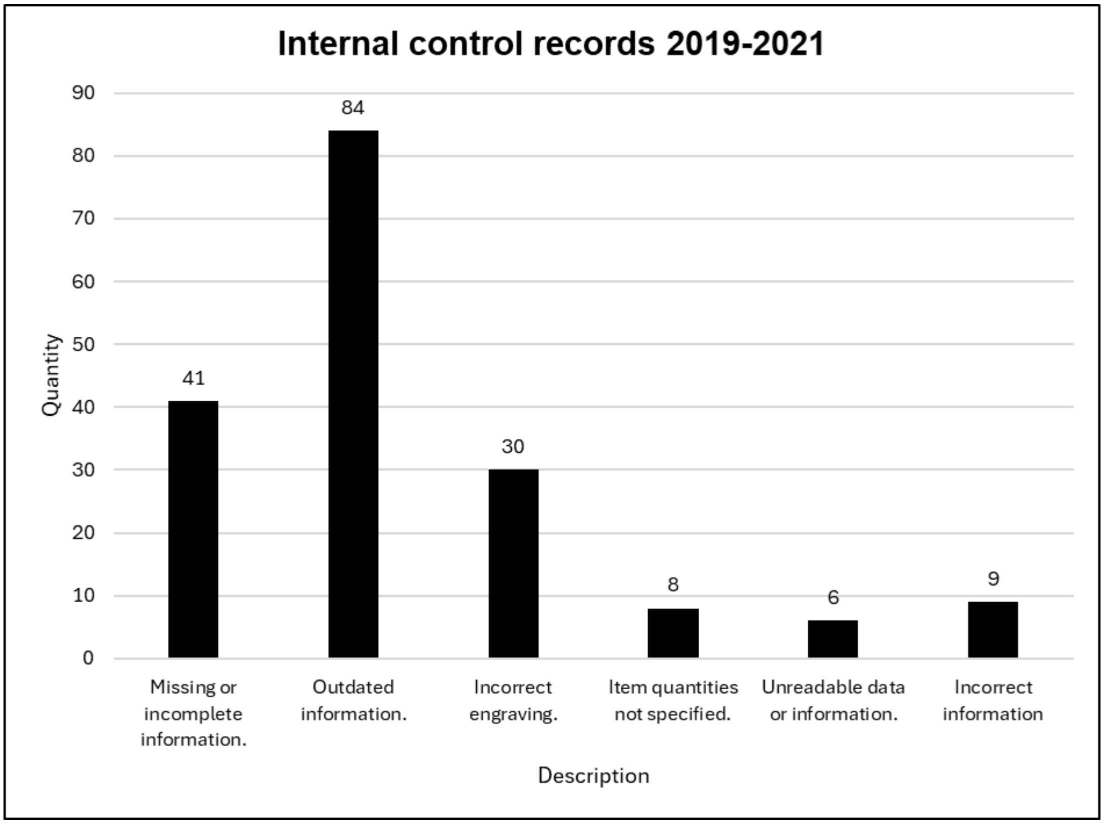

Figure 1. Records of Internal Control errors for the years 2019-2021

2. OBJECTIVES

To use techniques to analyze human reliability through data collection with the HTA and to qualitatively and quantitatively evaluate human reliability to classify and predict human errors using the SHERPA method and thereby propose concrete recommendations to reduce the probability of human errors.

3. DELIMITATION

This study seeks particularly to analyze human errors in the task of “Making drawings of parts and bills of materials” of the design department of a company in Cd. Juarez Chihuahua Mexico, dedicated to designing and manufacturing various tools for manufacturing processes of electronic boards of the local industry, proposes recommendations.

4. METHODOLOGY

This descriptive study seeks to analyze and classify the types of human error in the design process. The study will be carried out in two steps as shown in Figure 1, in the first step (HTA, Hierarchical Task Analysis) is hierarchical task analysis to break down the operations of the process of making drawings of parts and bills of materials, and the second step will consist of developing the SHERPA (Systematic Human Error Reduction and Prediction Approach) method, to qualitatively and quantitatively assess the reliability and where the taxonomies established to the type of error associated with specific operations within the task will be identified.

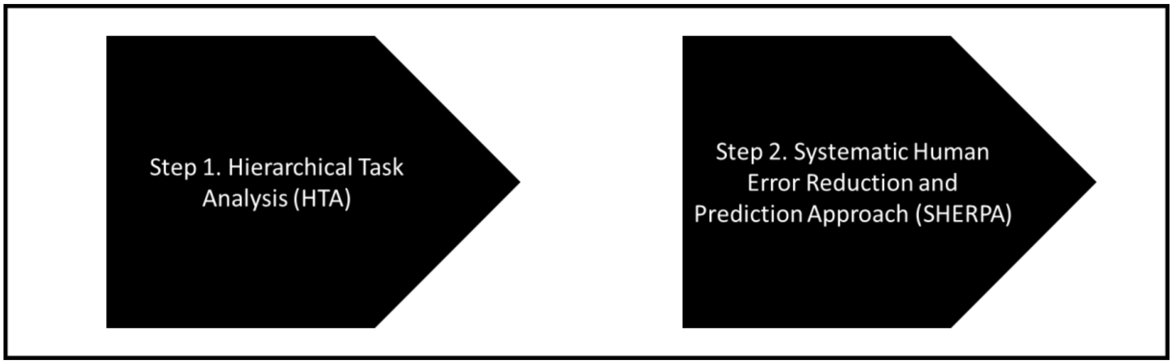

Figure 1. Steps in the methodology.

1.1 Hierarchical Task Analysis (HTA).

According to the methodology proposed by Stanton (2005), HTA is carried out by making a diagram showing a breakdown of hierarchical terms by objects, sub-objects, operations, and plans as shown in Figure 2.

1.2 Systematic Human Error Reduction and Prevention Analysis (SHERPA) Method

In this stage, the methodology proposed by Stanton 2005 will be developed. Thus, once the hierarchical task analysis has been performed, the task will be classified from the lower level of the hierarchical task analysis to the higher one, and the error modes will be classified according to the SHERPA taxonomy shown in Figure 3. He/she should then determine and describe the consequences associated with each error mode; furthermore, he/she should determine the recovery from the identified error. Also, once these steps are completed, you should determine the probability of occurrence of the error, its criticality, and how to remedy it through redesign, equipment modification, personnel training, changes to procedures, or changes in organizational culture and policies.

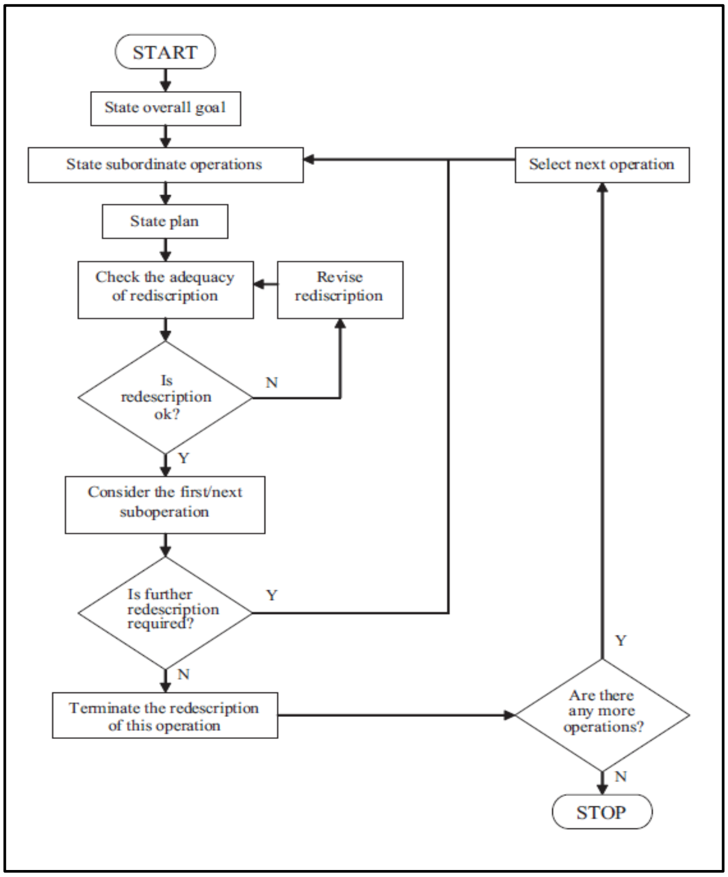

Figure 2. Hierarchical Task Analysis (HTA) Methodology

Action error		Checking error	
A1	Operation too long/short	C1	Check omitted
A2	Operation mistimed	C2	Check incomplete
A3	Operation in wrong direction	C3	Right check on wrong object
A4	Operation too little/much	C4	Wrong check on right object
A5	Misaligned	C5	Check mistimed
A6	Right direction on wrong object	C6	Wrong check on wrong object
A7	Wrong operation on right object	Selection error	
A8	Operation omitted	S1	Selection omitted
A9	Operation incomplete	S2	Wrong selection made
A10	Wrong operation on wrong object		
Retrieval error		Information communication error	
R1	Information not obtained	I1	Information not communicated
R2	Wrong information obtained	I2	Wrong information communicated
R3	Information retrieval incomplete	I3	Information communication incomplete

Figure 3. Taxonomic error mode.

5. RESULTS

The results of this study were organized into the steps mentioned above and are shown below.

Step One. By collecting data through interviews with personnel directly and indirectly involved in the process and a thorough review of the activities, a hierarchical task analysis was developed with the main tasks or activities, as well as subtasks included in each of the main tasks of the design process as shown in Figure 4.

Task 4, the subject of this study and described as 'creating part drawings and material lists,' was broken down into 17 subtasks that comprise the main task in a sequential plan format, as shown in Figure 5.

Step Two. Applying the SHERPA method to task 4, the classification of subtasks was carried out according to the taxonomies of the method (Figure 6), identifying error modes and finding between 1 and 4 error modes related to the method in each subtask. A total of 26 human errors were identified, of which 25 were action errors (96.15%) and 1 was a selection error (3.84%). The most frequently identified taxonomies were "omitted activity" with 13 occurrences, followed by "incomplete activity" with 9, "activity too short or too long" with 1, "too few or too many activities" with 1, and "incorrect selection" with 1. The criticality and probability, together, define a level of risk of error occurrence; the level found in the analyzed subtasks was high in 18 (69.23%) of them and medium in 8 (30.77%). Recovery strategies mainly involve the use of the individual's attentional resources, which include verification and observation activities.

6. CONCLUSIONS

The development of the hierarchical task analysis contributed to detail in a specific way the tasks and subtasks required and included in the process, achieving a clear and precise map of all the activities involved in the design process. In addition to this, the hierarchical task analysis contributed essential information for the development of the SHERPA method for the identification and classification of human error, detecting areas of opportunity in which standardization of elements and tools that contribute to the reduction of activities will be proposed, in addition to this, error recovery strategies in a systematic way to avoid affecting subsequent stages and process flows.

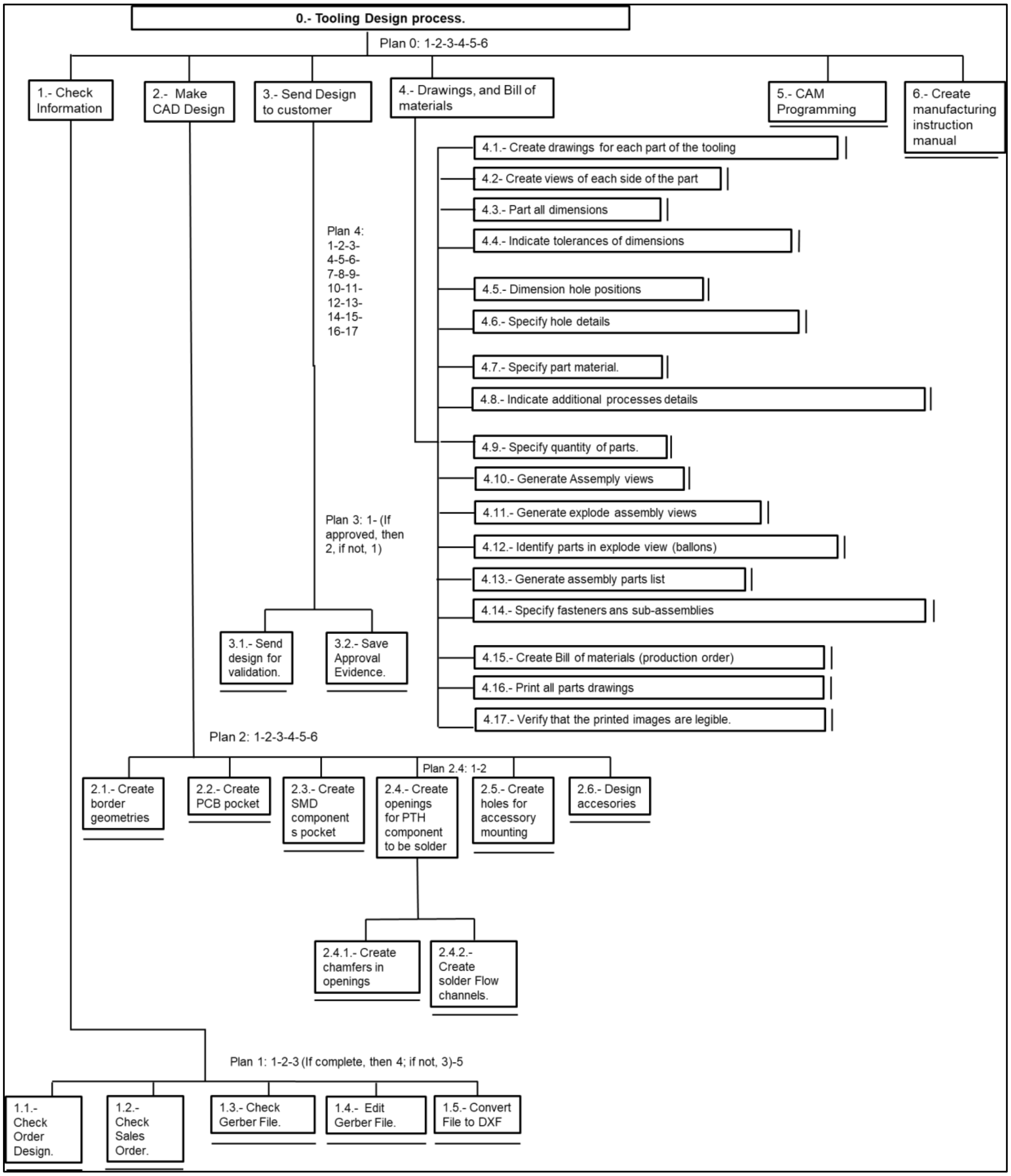

Figure 4. Hierarchical task analysis of the overall process.

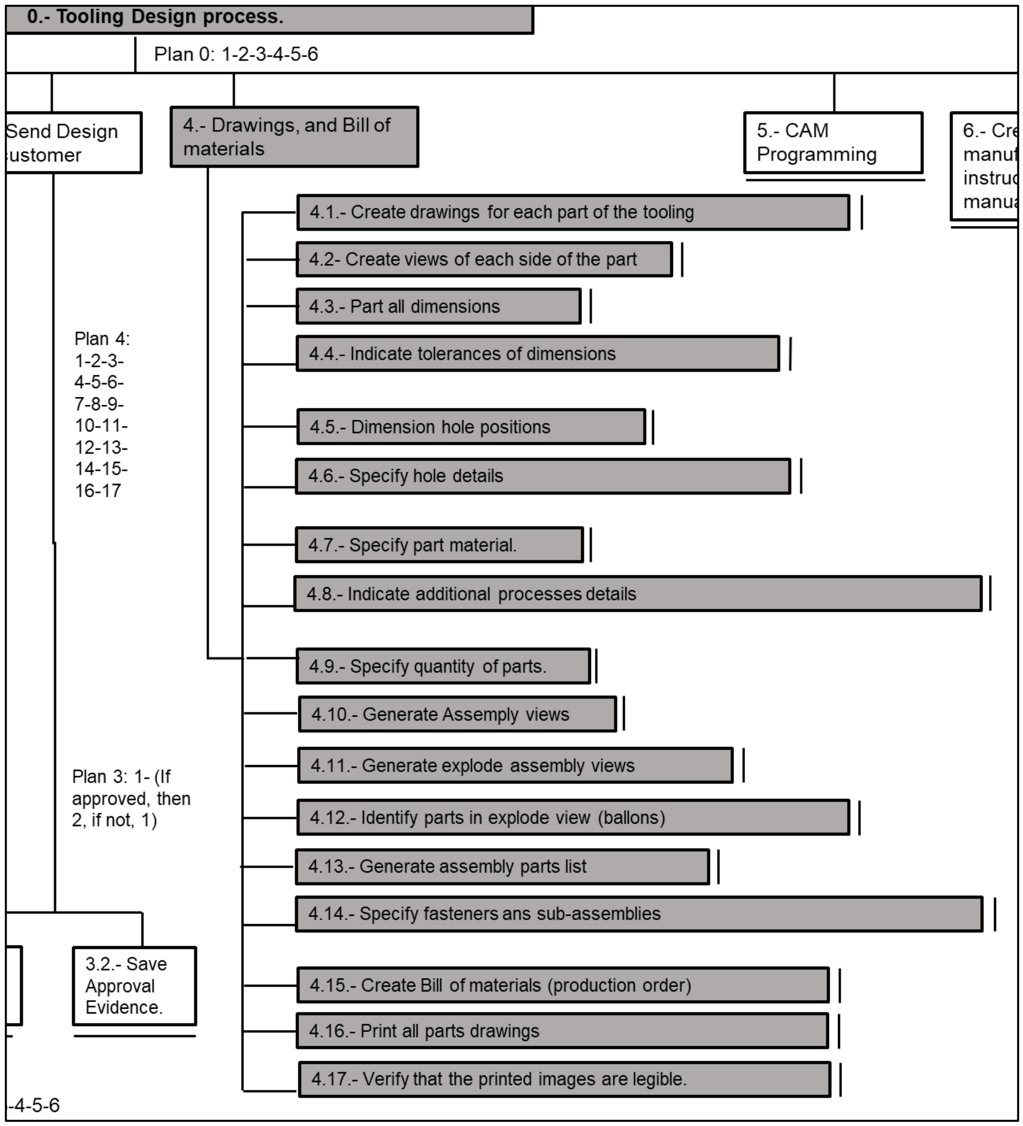

Figure 5. Detailed breakdown of Task 4

SHERPA output for task No.4.- Make part drawings and bill of materials.							
Step of Task	**Error Mode**	**Error Description.**	**Consecuences**	**Recovery**	**P**	**C**	**Recovery Startegy**
4.1.- Create drawings of each element of tooling	A1	Operation too long/short	Missing drawings	Task 4.1	H	_	Verify that the drawings of each part are available
	A4	Operation too little/much	Missing drawings and then they do not manufacture the part	Task 4.1	H	_	Verify that the drawings of each part are available
	A8	Operation omitted	Not manufacture the part	Task 4.1	H	_	Verify that the drawings of each part are available
	A9	Operation incomplete Wrong operation on wrong	Not manufacture the part	Task 4.1	H	_	Verify that the drawings of each part are available
4.2.- Create principal views of each part of tooling	A8	Operation omitted	No details of the parts are visible on the drawings.	Task 4.2	H	!	Verify that all views are present
	A9	Operation incomplete Wrong operation on wrong	No details of the parts are visible on the drawings.	Task 4.2	H	!	Verify that all views are present
4.3.- All dimensions of each part	A9	Operation incomplete Wrong operation on wrong	Part dimensions are missing and the part cannot be manufactured.	Task 4.3	H	_	Make sure all dimensions are present
	S2	Wrong selection made	The part is incorrectly dimensioned and poorly made.	Task 4.3	H	!	Verify that the dimension is correct.
4.4.- Indicate dimension tolerances.	A8	Operation omitted	The part is out of a functional size.	Task 4.4	H	!	Indicate tolerance on all dimension.
4.5.- Dimension Hole Positions	A8	Operation omitted	Drilling operation cannot be carried out	Task 4.5	H	!	Place the corresponding dimension
	A9	Operation incomplete Wrong operation on wrong	Drilling operation cannot be carried out	Task 4.5	H	_	Make sure all dimensions are present
4.6.- Specify Hole Characteristics	A8	Operation omitted	Incorrect drilling	Task 4.6	H	_	Make sure all dimensions are present
	A9	Operation incomplete Wrong operation on wrong	The hole is not functional	Task 4.6	H	!	Verify that the information is complete
4.7.- Specify Part Material	A5	Misaligned	Manufacture of the part with the wrong material	Task 4.7	H	!	Verify that the information is present and correct.
	A8	Operation omitted	Manufacture of the part with the wrong material	Task 4.7	H	!	Verify that the information is correct.
4.8.- Indicate Additional Processes if Applicable (Conventional Machining, Heat Treatment, Anodizing, Polishing, etc.)	A8	Operation omitted	Missing critical information to complete the part process	Task 4.8	H	!	Verify that it is indicated whether or not the part requires additional processing.
4.9.-Specify Quantity of Parts	A8	Operation omitted	Missing parts to complete the product	Task 4.9	M	_	Verify that the quantity of parts is indicated and is correct.
4.10.-Generate Assembly Views	A8	Operation omitted	Assembly details are not shown and features are omitted.	Task 4.10	M	_	Verify that the assembly view is present.
.11.- Generate Exploded Assembly View	A8	Actividad omitida	Assembly details are not visible and steps are omitted.	Task 4.11	M	_	Verify that the exploded view is present
4.12.-Identify Parts in the Exploded View (Balloons)	A8	Operation omitted	Items will not be fully identified	Task 4.12	M	_	Verify that the parts are identified in the explosion view
4.13.- Generate Assembly Parts List	A8	Operation omitted	That not all parts and quantities are contemplated and that it affects planning	Task 4.13	M	_	Verify that the assembly list is present for correct planning.
4.14.-Specify Fasteners and Sub-assemblies (Bolts, Pins, Nuts, Line Accessories, etc.)	A9	Operation incomplete Wrong operation on wrong	Wrong parts are placed	Task 4.14	H	_	Verify that the correct accessories are indicated.
4.15.- Create Bill of Materials (Production Order)	A9	Operation incomplete Wrong operation on wrong	Missing accessories to finish the product	Task 4.15	M	_	Verify that the bill of materials is complete and correct.
4.16.-Print All Part Drawings	A9	Operation incomplete Wrong operation on wrong	Missing drawings and parts are not made	Task 4.16	H	!	Verify that all drawings for product fabrication are in place.
4.17.- Verify that the Printed Images are Legible and Appropriately Sized	A8	Operation omitted	Measurements, details and characteristics of the parts are not legible.	Task 4.17	M	!	Verify that all drawings are legible and understandable.
	A9	Operation incomplete Wrong operation on wrong	Missing information and omission of important details	Task 4.17	M	!	Verify that all drawings are legible and understandable

Figure 6. SHERPA application in task 4.

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