A manufacturing resource is a physical machine or labor skill that is used in manufacturing artifacts. The manufacturing resource class has two subclasses: labor skill and manufacturing equipment. Labor skill represents labor rate and skill description. The manufacturing equipment subclass represents a piece of equipment (a physical entity). There are four subclasses: machine, die, mold and tool for machining. If necessary, other equipment classes may be added to the manufacturing equipment class. A piece of equipment has a set of parameters that describe equipment. A machine can be a machining centre, casting machine, forging machine, electrical discharge machine and so on. A machine has a set of parameters, such as dimension scope and tolerance scope. A tool represents a tool used in the machining process, such as a cutter, extender, holder and gauge. Each tool has a set of tool parameters. The tool class has four subclasses: cutting tool, ﬁxture tool, gauging tool and accessory tool. Manufacturing cost and time estimations have been built into the object model. The activity-based costing method has been adopted to form the basis for estimating the cost and time described in this paper. A manufacturing process consists of many manufacturing activities. Each manufacturing activity can be one of many processing activities, such as setup, load/unload, handling and processing. Each processing activity involves the cost of using any resources and overhead cost.

These three notions are interrelated, for example, a Process (e.g., casting, melting, milling, drilling) can utilize Resources (e.g., machines, raw materials, tools) in a production system, and the Process can also be used to define product qualification procedure [2]. In this sense, the coverage of the survey should not be restricted to the Process notion only, but also the Product and Resources notions which can affect the performance of a manufacturing process. Working with these three notions helps us to identify the inclusion and exclusion strategy of ontologies.

Product, Process, Resources are represented in ovals with their corresponding representative examples. The three notions are integrated inside a single-line rectangle, indicating that under the frame- work of a single manufacturing process, the representation of these three notions is static. The double-line rectangles illustrate the representation of dynamic objects. To optimize the dynamic production objectives (e.g., quality, precision, sustainability) under different environments, the selection of models, methods and tools need to be customized to generate appropriate and feasible solutions. The solutions include the suitable design of production processes and test procedures, the correct selection of equipment, validation of the producibility of products [2]. This generation necessitates the consideration of product constraints, such as the structure and functions of Prod- ucts. On the other hand, Resources can also influence the quality of Products and Processes. In this way, the three notions are mutually related and coherently integrated.