Chapter 4

Production Management Fundamentals for Additive Manufacturing

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Additional information is available at the end of the chapter

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Abstract

The additive manufacturing (AM) is a new way to produce parts, which in the last years had a significant application in the traditional production environment, since it demonstrated its capability to produce parts without particular defects and with good mechanical properties. During the last two decades the AM was firstly used to produce polymers' products and after metals' products; this evolution made possible the breakthrough in the traditional industrial sectors such as the aerospace, the mechanical, and other related sectors. Nevertheless, the introduction of this technology in this context put on the table of the researchers and practitioners some questions about the management of this technology in a more complex context, characterized by the integration with other machines. Aim of this chapter is to present a literature review of the principal facets of the AM related to the field of operations management and trying to define a model to account the costs of production and to schedule the machine activity.

Keywords: additive manufacturing, operations management, integration, scheduling, production cost accounting

1. Introduction

The industry is focusing its attention on additive manufacturing (AM) because it seems to be the way to realize a new industrial revolution. The first contribution about the AM appeared during the 90s [1] with a work by Massachusetts Institute of Technology (MIT); in this chapter, a first attempt to define the problem of the 3D manufacturing and its integration with the traditional way to produce the objects was described.

After this first contribution and many years, the 3D printing, or as it is named in a more detailed way the AM, arrived to the practitioners' world and many of the theoretic hypothesis and problems became real. The application of this technology in real cases or in the technological laboratories let to burst not only a lot of opportunities but also a lot of criticalities in its application.

In last years, the AM is employed in some first pilot production systems for the aerospace and aeronautic sector with application laboratories in collaboration with the MIT [2, 3]. Obviously, their productions are focused on small volume products since it is just a first attempt of experiments in this new field. From these first applications the industries, together with primary universities, are trying to understand the applicability of this new technology to substitute or at least to integrate their traditional production systems with these new ones, recognizing in the AM an opportunity to optimize their processes with particular attention to the design, engineering, production, and logistic.

The main problem for the practitioners and researchers, nowadays, is how to integrate this technology with the old, and which are the new paradigm to optimize the production using it.

The aim of this chapter is to present firstly a literature review that is able to cover three relevant sectors of the industrial systems management problem, two of these are related to the possibility to apply this technology to the industrial world (analyzing the mechanical characteristics of the materials worked and the tolerance of working achievable through AM) and a third, that is more referred to the management methods for the AM and in particular the measurement of costs for the processes of AM production methods and the scheduling models if present. After this literature review, a possible model to measure the costs using the AM will be presented and after a mathematical model to schedule the AM activities will be presented, giving the possibility to the reader to understand the decision problem and so to apply the resolution method preferred by him.

2. Literature review

Firstly, we will start from the materials and their resistance using AM. This is the first topic investigated in the international literature since its investigation is the first point to demonstrate the feasibility of this kind of technology in the industrial world.

The keywords investigated were several and reported below: (i) AM materials, (ii) AM tolerances in production, (iii) AM metallic materials, and (iv) AM polymeric materials and similar or combinations of the previous words.

The materials more studied using AM are the titanium alloys, even if also other materials are studied such as the Cr-Co alloys, stainless steel, and other metallic materials.

The first investigation about the materials is about the tolerances in production. This is a very felt issue in the production environment since it demonstrates the feasibility of the process, from a first point of view, and the need to integrate the technology with other old technologies to realize a finished part.

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The part orientation was demonstrated as influencing variable in the tolerances realization using AM since 2011 as it was reported in a paper in that year [4]. The paper focused the attention on the geometric tolerances related to the orientation of the part and, in fact, it was the first to do so. Before this study other study appeared, for example, the one by (i) Arni and Gupta in 1999 in which the planarity tolerance using an AM technology [5] was investigated and by Hanumaiah and Ravi for other linear geometric tolerances [6]. The tolerances were investigated also in relation with the production parameter by another study [7] that investigated the circularity in the AM in relation with the cutting angle of the starting point (i.e., the error is minimized if the starting cut angle is equal to 0°); going in deeper analysis on this relation, it is also possible to find another paper about the relation between geometric tolerances and production parameters by Lynn-Charney and Rosen [8] who studied and defined a new decision support system (DSS) capable to minimize the errors for positioning of the part in the production chamber and for some geometric tolerances.

Another problem in the AM production is the surface definition in the software file of the part, a paper that investigates this issue appeared in 2016 [9], in this chapter, it is defined a mathematical model to minimize the dimensional errors. Using this model, in an experimental campaign, the reduction of the 70% of the surface defects was eliminated.

Other authors investigated the effects on geometrical tolerances due to the thermal deformation of the melting process for the materials in the production chamber [10]. Other researchers [11] investigated the geometric errors of cylindrical shape dependent by the passage from the CAD model to the triangular shape for stereolithography and they built a new procedure to minimize it.

The geometrical and dimensional tolerances are a topic very felt also in other sectors such as the medical products. In this sector, it was found a contribution of 2015; in this chapter, it performed a sensitivity analysis on the several possible causes of the dimensional and geometrical errors that are possible in the production of this particular kind of objects [12]. The main elements of problem are (i) the quality of the image acquisition and printing, (ii) triangulation density, and (iii) segmentation threshold.

From the papers presented before, it is quite easy to understand that the AM technology is capable and maturely produces parts with good quality, so it is applicable to the industrial sector.

Once that the chapters on the tolerances in production were analyzed, they will be analyzed chapters referred to the mechanical properties of the materials produced with the AM technology.

The Ti-6Al-4 V material is used in many aerospace and mechanical sectors. In fact, as it is reported in a publication of 2015, the alloy Ti-6Al-4 V AM production is good to improve the *buytofly* index from a typical value of 15 to 1 for the aerospace industry [13]. This ratio is obtained using the raw materials compared with the weight of the components at the end of their production. For the Ti-6Al-4 V, using an electron beam melting (EBM) method is possible to have a deposition rate of 500 mm/s, with a moderate operational cost. In the paper by Szost, they reported the following defects for the EBM:

i. Vacancies of melting

ii. High-porosity of the materials.

The porosity of the materials produced with AM is a very important issue and this is evident since 2011 when a paper by Baufeld and others appeared [14]. In this chapter, it is fixed a limit value for the porosity of the materials to avoid the gas capture phenomenon and this limit is 6%.

Another paper reports the results of several mechanical tests of the alloy Ti-6Al-4 V when produced with AM (laser-beam deposition (LBD) and the shaped metal deposition (SMD)). In particular, it is interesting that for both the products it is not present any particular remark about the comparison with the traditional ones; they have a critical break tension of 900–1000 MPa and a starting tension for the plastic behavior to 770 MPa.

The production methods such as the EBM, the LBD, and the SMD characteristics are summarized in **Table 1**.

To remark what before stated it is possible also to refer to a paper appeared on 2015 [15] on the mechanical properties of the alloy Ni-Ti produced using the technology of shaped memory alloy (SMA). In this chapter, the controls performed are several reported below:

i. Scanning electron microscopy (SEM)

ii. Differential scanning colorimeter (DSC)

iii. X-ray diffraction (XRD)

iv. Micro-hardness test.

In all the tests, the products produced with the Ni-Ti alloy with SMA presented a very close behavior to the ones produced with traditional methods, confirming the goodness of the AM methods.

In 2015, a chapter focused its attention on the laser powder deposition (LPD) method that is very used in the spare parts prototyping; the paper mainly investigated a method to recognize defects during the production run that is ongoing [16].

	EBM	LBD	SMD
Max power (kW)	3	3.5	2.2
Max welding velocity (mm/s)	16.0	10.0	5.0
Max wire-feed velocity (mm/s)	25	40	33
Max wire diameter (mm)	1.0	1.2	1.2
Max height deposition step (mm)	0.1	1	1
Max deposition rate (kg/h)	0.1	0.7	0.6
Max wall thickness (mm)	10	4-5	9.1

Table 1. Production parameters used for EBM, LBD and SMD in Baufeld et al.

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Always on 2015, another paper appeared demonstrated the goodness of the parts realized in titanium alloys using the AM [17].

Another material used with the AM technology is the AlSi10Mg, that is, a no-metallic material. This material, when produced using the AM, has very similar mechanical characteristics when compared to the traditional production methods, as it was demonstrated in a paper where this fact was demonstrated using a DMLS technology [18].

From the literature analysis about the mechanical characteristics of the materials worked with AM technology is quite evident that the materials worked with this kind of technology are comparable at all with the traditional ones, except for some defects about the porosity of the materials, that can be faced with several adjustments and practices in the cycle or using a post-processing phase with traditional technologies.

Therefore, in conclusion, speaking in terms of quality of the final product, the AM processes are able to produce good parts, and so, it is possible to consider it in a production environment.

After the presentation of the process capability to realize good parts, let us continue with the operations management literature review.

Actually, different attention has to be paid to the operations management themes, since it is a research field for the AM not so much developed as the one about the materials and tolerances.

The operations management are the themes related to the: (i) production organization, (ii) production balancing, (iii) production quality, (iv) life cycle management, and (v) production sustainability.

The keywords investigated were strictly connected to the themes above mentioned with the adding of the AM words.

For the purpose of this chapter, they have analyzed 16 papers from several journals of the main scientific data base available nowadays.

A first contribution analyzed is from an Indian study about the costing in the operations for the prototypes production with metallic materials. In the paper [19], it is evidenced that the rapid prototyping (RP) finds great advantages from the AM application since it allows reducing dramatically the contribution of the production costs for a single piece.

Another contribution also in 2010 appeared in USA, the paper investigated the sustainability impact of AM production system [20]. In the paper, in particular, it is presented an assessment framework for the sustainability assessment for an AM production system, considering the following elements: (i) energy consumption, (ii) waste production, (iii) water usage, and (iv) environmental impact.

After these two first papers, for some years no particular research paper was published, maybe because the theme was too unripe. The theme was looked with interest once again in 2013, that is, after few years with the rising of the first possibility to bring the AM in the industrial context.

Actually, in 2013, they appeared some papers of interest for the AM operations research theme. In this year, they appeared a paper about a cost-benefit analysis between traditional and AM methods for RP operations performed [21]. The benefits are dominant to the costs when the AM is used instead of traditional production systems.

In 2014, another study appeared to prove the convenience of an AM, from the supply chain management point of view [22]. It is defined a decision framework for the application of this technology to a specific product, and the AM resulted in the best choice, especially when the product to be produced is very complex in shape.

Always on 2014 another implementation framework for the AM technology was proposed by another research group [23]. In this paper the authors tried to understand if there is a model of decision capable to help the technology selection using also the AM in the production environment. Another contribution about a very similar theme appeared in 2015 by the US-Chinese research group demonstrated the convenience of the AM considering the supply chain and life-cycle cost models [24].

The technology selection decision was also analyzed by another paper published on 2014 [25]. The framework is based on the evaluation of parameters such as the part complexity, the quantity to be produced and the level of customization that the product requires.

With the 2015 the research started to be more focused on the operations management optimization. Indeed, on 2015 the creation of DSS able to put at the right level of a bill of materials a part produced using the AM technology appeared; the model does this minimizing the life cycle cost and maximizing the value chain of the product [26].

On 2015 another paper focused on the insertion of the AM technology in traditional production systems appeared [27]. The paper deals with the identification of the main facets to be solved to make easy the AM insertion, referring principally to the operations management issues.

Always in the same year, a paper about the economic consequences of the AM use in a production company appeared [28]. The paper depicted the main economic variables applicable to the AM, such as the marginal costs of the production, the quality impacts on production economics, and so on. Very similar works about the economic facets related to the AM implementation in traditional production systems are present also in other paper such as [29, 30].

Another great theme about the economics issues related to the AM was investigated in another paper appeared on 2015. This paper faces the problem to define a selling price for an AM built part; this was done using the gray theory [31].

Also, the environmental and the other variables of the sustainability were deeply investigated as demonstrated from several publications in the international literature [32, 33].

Another theme investigated in the international literature is about the possibility and the framework to make feasible the integration of an AM technology with the traditional subtractive machines [34].

Therefore, the AM operations management facets are studied since the 2010 but they started to be mature in terms of study only from 2013, when some first publications about the possibility to analyze the AM from the costs and operations management perspective started to appear. After this year, (i.e. 2013) the number of papers in this field exponentially started to grow up (see **Figure 1**).

Nevertheless, it is quite obvious from the literature review analyzed that the operations management using AM is not well covered yet from the research point of view. Actually, this lack is well understandable from **Figure 2**, in which the operations management theme is reported in terms of number of papers appeared in the years.

The first points to be developed in the future are mainly focused on the definition of a proper cost accounting model and also a scheduling model for the AM.

The aim of this chapter is to introduce the reader to some first definition attempts by the author about these two specific issues.

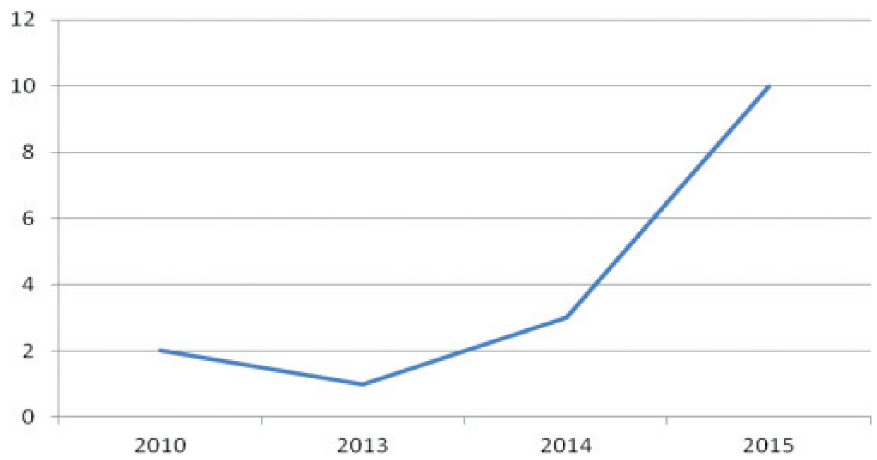

Figure 1. Number of operations management per year.

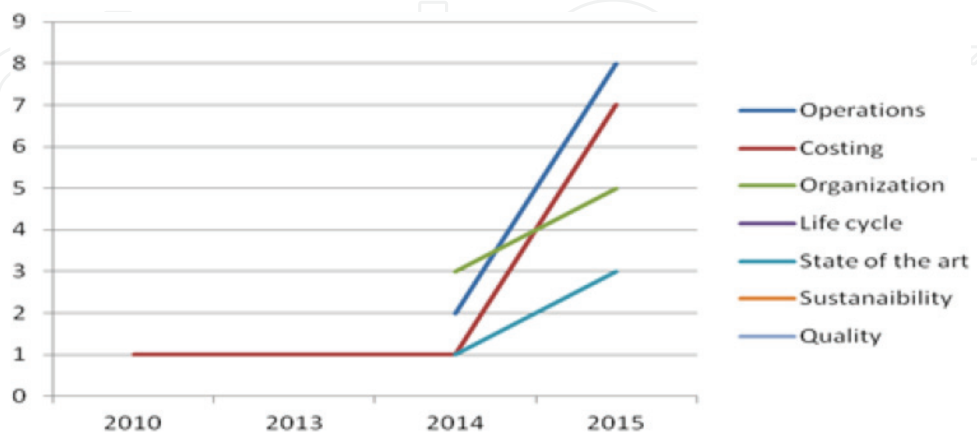

Figure 2. Number of publications per year and per theme.

3. The production cost model

The present model is summarized and reported by another paper of the authors appeared on 2017 [35–37].

3.1. Total manufacturing cost

The total manufacturing cost for each geometry is obtained by summing the cost of each step to finish a part belonging to a specific client order. The single elements of this formula will be developed and illustrated in the following part of this section, giving the possibility to anyone wants to replicate the cost calculation scheme here reported.

$$C_{tot}(G_i) = C_{prep}(G_i) + C_{buildjob}(G_i) + C_{setup}(G_i) + C_{build}(G_i) + C_{removal}(G_i) \quad (1)$$

Where:

C_{tot}: Total manufacturing cost of each part with *i*th geometry [€/part].

G_i: *i*th geometry [−].

C_{prep}: Cost for preparing geometry data (orientation, support structures, etc.) [€/part].

$C_{buildjob}$: Cost for build job assembly [€/part].

C_{setup}: Machine setup costs [€/part].

C_{build}: Cost for building up a part with *i*th geometry [€/part].

$C_{removal}$: Cost for removing the part with *i*th geometry from the machine chamber [€/part].

3.2. Cost for preparing geometry data

The first step of the process reported here is the design of the geometry data that includes orientation and support structure generation for each geometry. A possible formulation for this cost considers the specific value of a cost referred to the number of parts to be produced for each geometry, as reported in (2):

$$C_{prep}(G_i) = \left(C_{op.pre} + C_{PC}\right) * \frac{T_{prep}(G_i)}{N_i} \quad (2)$$

Where:

C_{prep}: Cost for preparing geometry data (orientation, support structures, etc.) [€/part].

G_i: *i*th geometry [−].

$C_{op.pre}$: Pre-processing operator's hourly rate [€/h].

C_{PC}: Hourly rate of the workstation including costs of required software and tools [€/h].

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T_{prep}: Time required for preparing CAD data [h].

N_i; Quantity of the part with ith geometry [−].

3.3. Cost for building job assembly

In the traditional approach, as reported in Rickenbacher et al. [38] this cost is allocated equally between all parts while in the present formulation this cost is allocated with a ratio that considers the how much volume each geometry occupies in the total volume given by the geometries inserted in the build camera, as reported in (3):

$$C_{buildjob}(G_i) = T_{buildjob} * \left(C_{op.pre} + C_{PC}\right) * \frac{V(G_i)}{\sum_i V(G_i) * N_i} \tag{3}$$

Where:

$C_{buildjob}$: Cost for build job assembly [€/part].

G_i: i-th geometry [−].

$T_{buildjob}$: Time required for build job assembly [h].

$C_{op.pre}$: Pre-processing operator's hourly rate [€/h].

C_{PC}: Hourly rate of the workstation including costs of required software and tools [€/h].

V: Volume of the geometry [cm^3].

N_i: Quantity of part with ith geometry [−].

3.4. Machine setup costs

When all the previous activities, that is, the preparing geometry and the planning phase are completed the real production phase can start. This phase includes the data import and machine setup phases. During this time, the machine cannot be used, and for this reason, we included its hourly cost. Also, in this case, we used the parts volume like the allocation criteria and the final formulation is as the one reported in (4):

$$C_{setup}(G_i) = \left(C_{op.mach} + C_{mach}\right) * \left(T_{setup} + \left(F_{mat.ch} * T_{mat.ch}\right)\right) * F_{inertgas} * \frac{V(G_i)}{\sum_i V(G_i) * N_i} \tag{4}$$

Where:

C_{setup}: Machine setup costs [€/part].

G_i: i-th geometry [−].

$C_{op.mach}$: Machine operator's hourly rate [€/h].

C_{mach}: Machine cost per hour [€/h].

T_{setup}: Time required for machine setup [h].

$F_{mat.ch}$: Factor to model the frequency of material changes [−].

$T_{mat.ch}$: Time required to change material [h].

$F_{inertgas}$: Factor to model extra effort required for handling in protective gas environment [−].

V: Volume of the geometry [cm^3].

N_i: Quantity of part with i-th geometry [−].

In the previous formula, it is also possible to include the possibility to work with an extra time of processing due to the use of protective gas ($F_{inertgas}$). Its value can either be 1 or 0. Also, the change of material can be considered using a 0/1 variable named ($F_{mat.ch}$). Furthermore, if the costs have to be divided on more build jobs, a fraction can be used in the formulation.

Machine cost per hour is obtained by dividing the machine purchase cost by the machine depreciation period and its uptime per year:

$$C_{machine} = \frac{Machine\ cost}{h*upt} \tag{5}$$

Where:

$C_{machine}$: Machine cost per hour [€/h].

Machine cost: Machine purchase cost [€].

h: Machine depreciation period [years].

upt: Machine uptime [hours/year].

3.5. Cost for building up a part

After the presentation of the previous parts of the total production cost, let us to introduce the formula for the calculation of the building step. In this phase, the machine concurrently builds all of the parts in the chamber. The cost's items are:

- Machine
- Energy
- Material
- Gas

Therefore, it is possible to define the (6), that is the building cost formulation, which also includes a waste factor for the powder used in the deposition and sintering phase:

$$C_{build}(G_i) = T_{build}(G_i)*\left(C_{mach} + C_{inertgas}*Gas_{cons} + C_{energy}*P_{cons}*K_u\right) + M(G_i)*\left(C_{material}*W_f\right) \tag{6}$$

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Where:

C_{build}: Cost for building up a part with *i*th geometry [€/part].

G_i: *i*-th geometry [−].

T_{build}: Total building time [h].

C_{mach}: Machine cost per hour [€/h].

$C_{inertgas}$: Cost of inert gas [€/m^3].

Gas_{cons}: Average gas consumption [m^3/h].

C_{energy}: Mean energy cost [€/kWh].

P_{cons}: Power consumption [kW].

K_u: Utilization factor [−].

M: Mass of the geometry [kg].

$C_{material}$: Material costs [€/kg].

W_f: Waste factor for powder [−].

3.6. Cost for removing a part from the machine

When the operations of building up are concluded, it is necessary to remove the objects and the substrate plate from the machine chamber. Also, in this case, we included a factor to model, that is, capable to consider the extra time effort for handling in a protective gas environment the production phase. The allocation criteria of this cost are based on parts volume. The formula for this addendum of (1) is reported in (7):

$$C_{removal}(G_i) = T_{removal} * \left(C_{op.mach} + C_{mach}\right) * \frac{V(G_i)}{\sum_i V(G_i) * N_i} * F_{inertgas} \tag{7}$$

Where:

$C_{removal}$: Cost for removing the part with *i*th geometry from the machine chamber [€/part].

G_i: *i*th geometry [−].

$T_{removal}$: Time required for removing parts from the machine chamber [h].

$C_{op.mach}$: Machine operator's hourly rate [€/h].

C_{mach}: Machine cost per hour [€/h].

V: Volume of the geometry [cm^3].

N_i: Quantity of part with *i*th geometry [−].

$F_{inertgas}$: Factor to model extra effort required for handling in protective gas environment [−].

Substituting the single elements of the (1) with the equations from (2)–(7), it will be possible to consider the total cost formulation.

4. The scheduling problem for additive manufacturing (AM)

The AM scheduling is a problem, different from the traditional single machine scheduling, to be solved since this technology started to be a permanent part of the production environment of several companies especially in the field of defense and aerospace. The model presented here is a summary of what was presented in [39, 40]. The question to which the paper wants to answer is always the same of all scheduling problems, that is:

"What's the schedule that allows to respect due dates with the least production cost?"

The question is the same but the context as explained in the introduction is very different from the traditional one for the motivations are related to the set-up, that is no more present in the traditional form since it is done all through the design phase and the transferring of the data from the design workstation to the machine and since the fact that with AM it is possible to produce several kinds of geometries in the same production run. For this reason, let us introduce a multi-objective model for the AM schedule that is able to consider also the new constraints given by the new context.

The development framework (**Figure 3**) is like the ones for the traditional problems of *production scheduling, so the prod*uction orders are the inputs of AM machine scheduling problem and each order is characterized by the following attributes:

d_i:	demand of $G_i - th$ geometry or PN	$[part]$
dd_i:	due date of $G_i - th$ geometry or PN	$[day]$
V_i:	volume of $G_i - th$ geometry or PN	$[cm^3]$

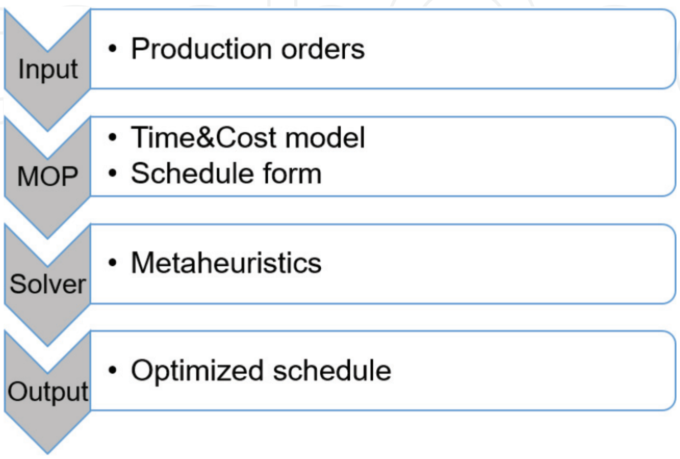

Figure 3. Mathematical model frame.

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After that the attributes for the production orders are listed, it is worth to note that in this paper a time and cost model will be applied, in particular, they will be considered the Completion Time (CT) and the Total Part Cost (TPC). CT is the time to produce a single unit of $G\_i - th$ geometry, while TPC is the costs to be covered to produce a single part.

Once the main description elements of our model is described let us to introduce the mathematical formulation of the optimization problem here analyzed. The basic model is taken from a research paper, that used earliness and tardiness as objective function [41], to these objectives in this proposal it is added the cost:

$$\boldsymbol{F_S = F_{ET} + F_{CP}} \qquad \textbf{Min}!$$

$$F_{ET} = \sum_{i=1}^{n_g} \left[\alpha_S E_i + \beta_S T_i\right]$$

$$F_{CP} = \sum_{i=1}^{n_g} \gamma_S TOC_i$$

Subject to:

$$\sum_{i=1}^{ng} n_{i,j} * V_i \le V_{chamber} \quad \forall j \in [1, n_b]$$

$$\sum_{j=1}^{nb} n_{i,j} = d_i, \quad \forall i \in [1, n_g]$$

$$\alpha_S, \beta_S, \gamma_S, TOC_i, V_i, V_{available} \in \mathbb{R}^+$$

$$E_i, T_i, i, j, n_g, n_b \qquad \in \mathbb{Z}^+$$

Where:

α_S :	Earliness constant weight	$[1/day]$
β_S :	Tardiness constant weight	$[1/day]$
E_i :	Earliness of *i–th* geometry	$[day]$
T_i :	Tardiness of *i–th* geometry	$[day]$
TOC_i:	Total Order Cost of the *i-th* geometry	[€]
γ_S :	Cost constant weight	[1/€]
n_g:	number of order/geometries	$[-]$
$n_{i,j}$	Number of the *i–th* item in *j–th* build	$[part]$
V_i	Volume of *i–th* geometry	$[cm^3]$
$V_{chamber}$	Build chamber volume	$[cm^3]$
n_b	Number of build in the schedule	$[-]$
d_i:	demand of $G_i - th$ geometry	$[part]$

The proposed scheduling model has some hypothesis that is listed below:

- The scheduling problem faced here is a Single-machine scheduling problem, where the machine is an AM machine.
- The part orientation is given and there is enough space to manually remove the part.

- The build chamber allows construction of parts on top of each other by support structures or other solutions.
- Stock costs are neglected.

To solve this kind of problems that are generally reported as *NP-hard* problems, it is possible to apply several kinds of heuristics such as Tabu Search, genetic algorithm, simulated annealing, ant colonies, bees, particle swarm optimization, and so on.

5. Conclusions

In this chapter, an attempt to analyze and categorize such themes related to the production issues of the AM technology was done. AM technology began becoming an industrial solution recently, and so it was recognized as an interesting theme with a possibility to deepen the research area if this technology achieved a good level of maturity in terms of mechanical resistance characteristics and tolerances achievable. After the first step analysis, the state of the researches about the operations management field was analyzed and investigated.

This chapter defines a precise way for the literature review, and it analyzes and categorizes several papers with the method introduced before.

From the literature analysis conducted, it was quite clear that from a technological and from a production quality level (measured from the capability to achieve such levels of geometrical and dimensional tolerances) not so many issues are open and so it is possible to conclude that the AM is quite ready to be brought in the industrial context, given some adjustment still needed about the processes to avoid the porosity problems for the parts worked with the AM technology and to achieve some geometrical tolerance as the concentricity and circularity. Therefore, the pieces in a metal can be realized directly using the AM technology, having a good level of reliability of the part, when it is under mechanical stress. Moreover, the parts realized in this way are good in terms of tolerances achievable, limiting the need of mechanical post-processing activities.

Starting from this result in this paper it was investigated if a scientific literature lacks on the possibilities of the AM to be a production technology in the industrial world exists or not. In fact, to make real the possibility to effectively bring this technology in the production context, it is required that the AM becomes more and more a theme studied and known from the operations management point of view, also offering the possibility to be measured in a production context. In fact, the technology is evolving, and the need to understand the production management issue is becoming a need. Therefore, it is possible to say that if from the point of view of the mechanical tolerances and properties a lot of work was performed and good results are available not the same can be said from the management point of view. Therefore, this state of the art can individuate as the first point of study an important issue about the methods to measure the process costs when an AM technology is used to produce an item.

Moreover, as argued in the previous paragraph, the management theme seems to be affected from a very important absence. Many authors have begun to study the management issues related to the general systems; however, nobody recognizes a main limit in the actual knowledge level.

Therefore, in this chapter, it was presented a cost allocation model that fits the requirements of this new technology and also a mathematical formulation for the scheduling problem of a single AM machine is presented.

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