**Table I1.** Unique ecosystem model for AM adoption in the defense sector, highlighting the evolving characteristics of the different constructs

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Construct** | **Actor** | **Content** | **Relevance/importance as AM adoption level progresses** | | | **Motivation** |
| **Increase** | **Decrease** | **Stable** |
| **Resources** | **Governmental bodies** | Communication & Outreach Programs |  | ✓ |  | This is linked to the activity “AM benefits campaigns”, which decreases its relevance (cf. below) |
| Funding & grants |  |  | ✓ | Although “Advanced-Stage Adopters” attribute lower relevance to the countermeasures linked to governmental fundings and support, they all recognize their importance. However, the focus of the fundings & grants needs to shift as AM adoption progresses (cf. activity construct) |
| **Legal & Regulatory Bodies** | Regulation and standardization power | ✓ |  |  | The relevance of the challenge “Standardization and Certification” (C6) increases moving from “Early-Stage Adopters” to “Advanced-Stage Adopters”, and this resource is linked to such challenges |
| Legal expertise | ✓ |  |  | This is linked to the challenge C4 (“IP Issues & Data Breaches”): as its relevance increases as AM adoption progresses, so does the need for Legal and regulatory bodies to use their legal expertise to overcome it |
| Staff |  |  | ✓ | No identifiable changes in the need of staff, which will of course be needed |
| **HEIs & research entities** | Knowledge on AM |  |  | ✓ | This is an obvious resource and it is not expected to change |
| Training facilities & equipment |  | ✓ |  | As it emerged from the analysis of the countermeasures (Section 4.3), training-related countermeasures are attributed a high relevance by “Early-Stage Adopters” but not by “Advanced-Stage Adopters”. Therefore, training facilities & equipments are no longer required as AM adoption progresses |
| Research facilities & equipment | ✓ |  |  | As AM adoption level progresses, HEIs are no longer (or at least less) required to focus on training (cf. below the construct activity) and they can hence focus on R&D activities and on the development of guidelines for optimal production process parameters, design strategies, … Therefore, the relevance of this resource increases |
| Skilled workforce/staff |  |  | ✓ | No identifiable changes in the need of staff, which will of course be needed |
| Theoretical modeling capabilities (e.g. game theory, …) | ✓ |  |  | “Advanced-Stage Adopters” suggested “Ecosystem models – Develop ecosystem models to provide guidance and ensure all partners benefit from being part of it” as countermeasure to C14 (“Difficult ecosystem establishment”), which requires this resource. As AM adoption level progresses, the need for ecosystem that are beneficial for all actors involved becomes more and more crucial |
| **OEMs** | Knowledge on AM |  |  | ✓ | This is an obvious resource and it is not expected to change |
| IP rights | ✓ |  |  | The relevance of the challenge “IP Issues & Data Breaches” (C4) increases as AM adoption level progresses (cf. Section 4.1.2). Additionally, as AM adoption level progresses, more parts are being produced |
| Skilled workforce/staff |  |  | ✓ | No identifiable changes in the need of staff, which will of course be needed |
| AM machines |  |  | ✓ | The relevance remains stable. In the early stages, OEMs might lease their machines to support AM adoption. As the adoption level increases, leasing activities might end, but then OEMs focuses on R&D and research activities, which require AM machines (cf. below) |
| **AM technology & material providers** | Knowledge on AM |  |  | ✓ | This is an obvious resource and it is not expected to change |
| Skilled workforce/staff |  |  | ✓ | No identifiable changes in the need of staff, which will of course be needed |
| R&D capabilities | ✓ |  |  | As AM adoption level progresses, AM technology & material providers are no longer (or at least less) required to focus on training (cf. below the construct activity) and they can hence focus on R&D activities. Therefore, the relevance of this resource increases |
| AM machines |  |  | ✓ | The relevance remains stable. In the early stages, OEMs might lease their machines to support AM adoption. As the adoption level increases, leasing activities might end, but then OEMs focuses on R&D and research activities, which require AM machines (cf. below) |
| **Defense & Military Organizations** | Military-specific knowledge |  |  | ✓ | This is an obvious resource and it is not expected to change |
| Distributed AM machines | ✓ |  |  | As AM adoption progresses, more AM machines will be deployed |
| Consolidated network and infrastructure | ✓ |  |  | In the advanced stages, the network (e.g. suppliers) and infrastructure (e.g. AM machines) have already been established |
| Skilled workforce/soldiers |  |  | ✓ | No identifiable changes in the need of staff, which will of course be needed |
| Knowledge on AM |  |  | ✓ | This is an obvious resource and it is not expected to change. Their knowledge and skills will however increase as AM adoption level progresses |
| Collaboration network with foreign partners |  | ✓ |  | Although the related countermeasure was suggested only by “Advanced-Stage Adopters”, this is more relevant in the early stages of adoption to overcome challenges linked to high costs (C2) |
| **Activities** | **Governmental bodies** | Provide funding opportunities |  | ✓ |  | As evidenced by the analysis of the countermeasures (cf. Section 4.3), according to “Advanced-Stage Adopters”, funding opportunities to purchase AM machines or AM-related equipment are less relevant as the network and infrastructure is already established |
| Provide research/R&D grants | ✓ |  |  | Funding linked to R&D activities becomes more relevant as AM adoption progresses. It is true that relevance attributed by “Advanced-Stage Adopters” to these countermeasures is lower than that attributed by “Early-Stage Adopters”, but this is linked to their disillusion as such grants are often lacking (cf. Section 4.3), forcing them to find different solutions for the challenges linked to the “technological constraints” which increase as AM adoption progresses (cf. Section 4.1) |
| AM benefits campaigns |  | ✓ |  | This is linked to the countermeasure “AM benefits campaigns – develop awareness campaign on AM benefits”, which was not even suggested by “Advanced-Stage Adopters” as this is not required since when AM adoption is high, its benefits are already known (cf. Section 4.3) |
| **Legal & Regulatory Bodies** | Development of regulation & standards | ✓ |  |  | This represents one of the countermeasures to “Standardization and Certification” (C6) (cf. Section 4.3). As the relevance of this challenge increases moving from “Early-Stage Adopters” to “Advanced-Stage Adopters”, so does the relevance of this activity |
| Development of IP licensing agreements | ✓ |  |  | This represents one of the countermeasures to “IP Issues & Data Breaches” (C4) (cf. Section 4.3). As the relevance of this challenge increases moving from “Early-Stage Adopters” to “Advanced-Stage Adopters”, so does the relevance of this activity |
| Development of supplier qualification programs |  | ✓ |  | This is linked to the countermeasure “Qualified Supplier Program – establish supplier qualification programs to accelerate the onboarding of new suppliers” to the challenge C1 (“Lack of supplier”). This countermeasure was identified only by “Advanced-Stage Adopters” but, based on the analysis of the relevance attributed to the challenge C1 (cf. Section 4.1.2), it is more relevant at the early stages of AM adoption when no network has been established yet |
| **HEIs & research entities** | Develop AM-related study programs/courses |  | ✓ |  | As AM adoption level progresses, there is less need for training and AM-related study programs/courses have already been developed. Please refer to “Training facilities & equipment” in the construct resources for a better explanation |
| Provide training & workforce development programs |  | ✓ |  |
| Support in R&D activities | ✓ |  |  | The relevance of countermeasures linked to R&D developments (e.g. “High-performance AM machine development – R&D activities to develop AM machines with improved performance”) decreases moving from “Early-Stage Adopters” to “Advanced-Stage Adopters”. As it emerged from the comments received, this is however linked to the disillusion of practitioners that such developments will not be possible due to limited governmental fundings. However, as it can be observed, their relevance is still high, meaning that practitioners would welcome such developments. As AM adoption level progresses and HEIs are no longer (or at least less) required to focus on training, then they can focus on these R&D-related activities |
| Participate/lead research projects/initiatives | ✓ |  |  |
| Develop ecosystem models to ensure a successful, long-lasting AM adoption | ✓ |  |  | Please refer to “Theoretical modeling capabilities (e.g. game theory, …)” in the construct resources |
| Support to determine/determine optimal production process parameters, design strategies, etc |  |  | ✓ | Although the related countermeasure was suggested only by “Advanced-Stage Adopters”, this is very relevant also in the early stages of adoption to overcome different relevant challenges (cf. Section 4.3), especially when R&D developments have not yet occurred |
| **OEMs** | Provide training & workforce development programs |  | ✓ |  | As AM adoption level progresses, there is less need for training and workforce development program as the required skills and knowledge have already been acquired |
| Sustained collaboration with the ecosystem (especially willingness to share IP rights) | ✓ |  |  | As discussed for resources, as AM adoption level progresses, more parts are being produced, potentially leading to a higher probability of IP-related issues |
| Participate/lead research projects/initiatives | ✓ |  |  | The relevance of countermeasures linked to R&D developments (e.g. “High-performance AM machine development – R&D activities to develop AM machines with improved performance”) decreases moving from “Early-Stage Adopters” to “Advanced-Stage Adopters”. As it emerged from the comments received, this is however linked to the disillusion of practitioners that such developments will not be possible due to limited governmental fundings. However, as it can be observed, their relevance is still high, meaning that practitioners would welcome such developments. As AM adoption level progresses and OEMs are no longer (or at least less) required to focus on training, then they can focus on these R&D-related activities |
| Lease AM machines |  | ✓ |  | Leasing AM machines is an efficient way to overcome high investment costs (C2). This is particularly crucial in the early stages, but when AM adoption increases and more parts are being produced, the investment costs are spread over more parts, hence increasing AM convenience |
| Support to determine/determine optimal production process parameters, design strategies, etc. |  |  | ✓ | Although the related countermeasures were suggested only by “Advanced-Stage Adopters”, these are very relevant also in the early stages of adoption to overcome different relevant challenges (cf. Section 4.3), especially when R&D developments have not yet occurred |
| Concur to develop internal production guidelines |  |  | ✓ |
| **AM technology & material providers** | Carry out R&D activities | ✓ |  |  | The relevance of countermeasures linked to R&D developments (e.g. “High-performance AM machine development – R&D activities to develop AM machines with improved performance”) decreases moving from “Early-Stage Adopters” to “Advanced-Stage Adopters”. As it emerged from the comments received, this is however linked to the disillusion of practitioners that such developments will not be possible due to limited governmental fundings. However, as it can be observed, their relevance is still high, meaning that practitioners would welcome such developments. As AM adoption level progresses and HEIs are no longer (or at least less) required to focus on training, then they can focus on these R&D-related activities |
| Participate/lead research projects/initiatives | ✓ |  |  |
| Develop new AM solution/processes/materials | ✓ |  |  |
| Support to determine/determine optimal production process parameters, design strategies, etc. |  |  | ✓ | Although the related countermeasures were suggested only by “Advanced-Stage Adopters”, these are very relevant also in the early stages of adoption to overcome different relevant challenges (cf. Section 4.3), especially when R&D developments have not yet occurred |
| Concur to develop internal production guidelines |  |  | ✓ |
| Lease AM machines |  | ✓ |  | Leasing AM machines is an efficient way to overcome high investment costs (C2). This is particularly crucial in the early stages, but when AM adoption increases and more parts are being produced, the investment costs are spread over more parts, hence increasing AM convenience |
| Concur to develop supplier qualification programs |  | ✓ |  | This is linked to the countermeasure “Qualified Supplier Program – establish supplier qualification programs to accelerate the onboarding of new suppliers” to the challenge C1 (“Lack of supplier”). This countermeasure was identified only by “Advanced-Stage Adopters” but, based on the analysis of the relevance attributed to the challenge C1 (cf. Section 4.1.2), it is more relevant at the early stages of AM adoption when no network has been establish yet |
| Provide trainings on using AM machines |  | ✓ |  | As AM adoption level progresses, there is less need for training and workforce development program as the required skills and knowledge have already been acquired |
| Improve AM machines IT safety |  | ✓ |  | This is only required in the early stages. Once this is solved, then it is no longer required (indeed, “Advanced-Stage Adopters” did not suggest the corresponding countermeasure) |
| **Defense & Military Organizations** | Support staffs’ education |  | ✓ |  | As evidenced by the analysis of the countermeasures (cf. Section 4.3), training has a higher relevance in the early adoption stages. As AM adoption progresses, soldiers have gained the required knowledge on AM, which was instead lacking in the early adoption stages |
| Willingness to adopt AM and to integrate it in field operations | ✓ |  |  | This increases as the initial successful applications will encourage a wider adoption |
| Improve IT systems |  | ✓ |  | As discussed above, “Advanced-Stage Adopters” did not suggest “IT security” as countermeasure to the challenge “IP Issues & Data Breaches” |
| Internal training for new members (if needed) | ✓ |  |  | As discussed above, as AM adoption level progresses, soldiers have gained the required knowledge on AM and they can provide internal training to new members if needed, without the need of referring to other actors |
| Military asset sharing |  | ✓ |  | As AM adoption progresses, militaries are expected to have their own printers. On the contrary, at the early stages, sharing the printers with different partners can be an effective way to reduce the impact of investment-related challenges (C2) |
| Support to determine/determine optimal production process parameters, design strategies, etc. |  |  | ✓ | Although the related countermeasures were suggested only by “Advanced-Stage Adopters”, these are very relevant also in the early stages of adoption to overcome different relevant challenges (cf. Section 4.3), especially when R&D developments have not yet occurred |
| Concur to develop internal production guidelines |  |  | ✓ |
| **Value addition** | **Governmental bodies** | Funding & investment for AM adoption diffusion |  | ✓ |  | Please refer to “Provide funding opportunity” in the activity construct |
| Funding & investment in AM development through research/innovation projects | ✓ |  |  | Please refer to “Provide research/R&D grants” in the activity construct |
| Widespread knowledge on AM benefits |  | ✓ |  | Please refer to “AM benefits campaigns” in the activity construct |
| **Legal & Regulatory Bodies** | New AM standards | ✓ |  |  | Please refer to “Development of regulation & standards” in the activity construct |
| IP protection & licensing regulations | ✓ |  |  | Please refer to “Development of IP licensing agreements” in the activity construct |
| New qualified suppliers |  | ✓ |  | Please refer to “Development of supplier qualification programs” in the activity construct |
| **HEIs & research entities** | Establishment of AM-related courses and study programs |  | ✓ |  | Please refer to “Develop AM-related study programs/courses” in the activity construct |
| Establishment of lifelong learning programs and external teaching |  | ✓ |  | Please refer to “Provide training & workforce development programs” in the activity construct |
| Graduation of AM market-oriented students | ✓ |  |  | As AM adoption level progresses, more and more students with knowledge on AM will be required by the market. Therefore, more and more students will be attracted by such carreer, increasing the number of graduation |
| Generation of scientific & technological knowledge with consequent technology transfer possibilities to create new AM machines/materials | ✓ |  |  | As HEIs & research entities will focus more on R&D activities as AM adoption level progresses, more research breakthroughs and innovations can be expected |
| Successful ecosystem models to spread AM adoption | ✓ |  |  | Please refer to “Develop ecosystem models to ensure a successful, long-lasting AM adoption” in the activity construct |
| Guidelines and procedures for optimal production process parameters, design procedures, etc., resulting in cheaper and higher quality parts, faster production, … |  |  | ✓ | Please refer to “Support to determine/determine optimal production process parameters, design strategies, etc” in the activity construct |
| **OEMs** | IP licensing and sharing through controlled IP-sharing agreements | ✓ |  |  | Please refer to “Sustained collaboration with the ecosystem (especially willingness to share IP rights)” in the activity construct |
| Establishment of training programs |  | ✓ |  | Please refer to “Provide training & workforce development programs” in the activity construct |
| Guidelines and procedures for optimal production process parameters, design procedures, etc., resulting in cheaper and higher quality parts, faster production, … |  |  | ✓ | Please refer to “Support to determine/determine optimal production process parameters, design strategies, etc.” and “Concur to develop internal production guidelines” in the activity construct |
| Increased accessibility to AM machines due to leasing possibilities |  | ✓ |  | Please refer to “Lease AM machines” in the activity construct |
| **AM technology & material providers** | Development of new AM machines/solutions/raw materials | ✓ |  |  | Please refer to “Develop new AM solution/processes/materials” in the activity construct |
| Possibility to produce AM products faster, with lower costs and better quality | ✓ |  |  | As new AM machines will be developed as AM adoption level progresses, this value addition increases in relevance |
| Establishment of training programs |  | ✓ |  | Please refer to “Provide trainings on using AM machines” in the activity construct |
| Guidelines and procedures for optimal production process parameters, design procedures, etc., resulting in cheaper and higher quality parts, faster production, … |  |  | ✓ | Please refer to “Support to determine/determine optimal production process parameters, design strategies, etc” and “Concur to develop internal production guidelines” in the activity construct |
| Increased accessibility to AM machines due to leasing possibilities |  | ✓ |  | Please refer to “Lease AM machines” in the activity construct |
| New qualified suppliers |  | ✓ |  | Please refer to “Concur to develop supplier qualification programs” and “Concur to develop internal production guidelines” in the activity construct |
| **Defense & Military Organizations** | AM staff training |  | ✓ |  | As discussed above, training has a higher relevance in the early adoption stages where soldiers are lacking the required knowledge on AM |
| Use AM for field operations | ✓ |  |  | This is a natural consequence of the increased AM adoption |
| Guidelines and procedures for optimal production process parameters, design procedures, etc., resulting in cheaper and higher quality parts, faster production, … |  |  | ✓ | Please refer to “Support to determine/determine optimal production process parameters, design strategies, etc” and “Concur to develop internal production guidelines” in the activity construct |
| Improved IT systems |  | ✓ |  | The lack of the activity “Improve IT systems” from the “Advanced-Stage Adopters”-based ecosystem explains why this value addition is missing from such ecosystem |
| Increased accessibility to AM machines due to resource sharing |  | ✓ |  | Please refer to “Military asset sharing” in the activity construct |
| **Value capture** | **Governmental bodies** | Economic growth, job creation, higher tax income | ✓ |  |  | As AM adoption level progresses, a wider use of AM and an increase in number of suppliers can be expected, leading to this value capture |
| Improved national security and autonomy through increased supply chain resilience and responsiveness | ✓ |  |  | As AM adoption level progresses, a wider use of AM can be expected, which would lead to a greater realization of its opportunities O1, O5, O8, O12, which would increase supply chain resilience and responsiveness and reduce costs |
| Cost savings in defense procurement | ✓ |  |  |
| **Legal & Regulatory Bodies** | High satisfaction on AM standards | ✓ |  |  | As AM adoption level progresses, the use of standards increases, being accompanied by a high satisfaction on them as they are now available |
| IP-control, licensing, and standards-related revenues | ✓ |  |  | As AM adoption level progresses, a wider use of AM can be expected, leading to higher revenues for IP control activities and sales of standards |
| **HEIs & research entities** | Support for AM-related research activities | ✓ |  |  | As Governmental bodies will provide more R&D grants as AM adoption level progresses (cf. above), then HEIs & research entities will have more support for AM-related research activities |
| New and attractive study programs/courses |  | ✓ |  | The relevance decreases since new study programs/courses will be established at the early stages; as adoption progresses, these are expected to be just slightly improved |
| New AM-skilled staffs for next-gen AM materials/machines | ✓ |  |  | As HEIs and research entities are responsible of/involved in R&D activities, they are at the forefront of the development of new machines/materials, which allows to be always on top of new innovations and to master them before others. Since the focus on R&D activities is expected to increase in the later stages, the relevance of this value capture is expected to increase accordingly |
| Academic leadership in AM | ✓ |  |  |
| Closer connection with the military industry (gaining partnerships with military & industry for practical AM solutions) | ✓ |  |  | As AM adoption level progresses, HEIs & research entities focus on activities that are of increasing relevance for the military. Additionally, thanks to the training provided in the early adoption stages, a strong connection with the military is established |
| Increased student satisfaction |  |  | ✓ | Given the constant connection with the real world, courses will always be up to date |
| **OEMs** | IP monetization & licensing agreements | ✓ |  |  | As the IP licensing and sharing increases as AM adoption level progresses (see above), then the corresponding monetization will also increase |
| New AM-skilled staffs for next-gen AM materials/machines | ✓ |  |  | As OEMs are responsible of/involved in R&D activities, they are at the forefront of the development of new machines/materials, which allows to be always on top of new innovations and to master them before others. Since the focus on R&D activities is expected to increase in the later stages, the relevance of this value capture is expected to increase accordingly |
| Enhanced competitive advantage over competitors | ✓ |  |  |
| AM machines leasing monetization |  | ✓ |  | As the leasing of AM machines decrease as AM adoption progress (cf. activities construct), so does the related monetization |
| **AM technology & material providers** | Increased market opportunities and revenues (new AM machines and materials) | ✓ |  |  | As AM adoption level progresses, new machines and materials are expected to be developed thanks to the R&D activities and projects. This will create an advantage over competitors, leading to increased market opportunities and revenues |
| Support for AM-related research activities | ✓ |  |  | As Governmental bodies will provide more R&D grants as AM adoption level progresses (cf. above), then AM technology & material providers will have more support for AM-related research activities |
| New qualified suppliers |  | ✓ |  | As discussed above for both “Legal & Regulatory Bodies” and “AM technology & material providers” (cf. construct activities), new suppliers are required in the early adoption stages, where they are more needed |
| AM machines leasing monetization |  | ✓ |  | As the leasing of AM machines decrease as AM adoption progress (cf. activities construct), so does the related monetization |
| **Defense & Military Organizations** | Increased operational readiness and stability |  |  | ✓ | This derives from the realization of the opportunities O1, O5, O8, and O13. From the analysis of such opportunities, we can see how they are characterized by a stable relevance, which reflects also here in the value addition |
| Improved equipment functionalities | ✓ |  |  | This derives from the realization of the opportunities O4, O9, and O10. From the analysis of such opportunities, we can see how they are characterized by an increasing relevance as AM adoption level progresses, which reflects also here in the value addition |
| Lean and agile operations |  |  | ✓ | This derives from the realization of the opportunities O6, O7, and O8. From the analysis of such opportunities, we can see how they are characterized by a stable relevance, which reflects also here in the value addition |
| Increased operational flexibility and adaptability |  |  | ✓ | This derives from the realization of the opportunities O5, O11, and O13. From the analysis of such opportunities, we can see how they are characterized by a stable relevance, which reflects also here in the value addition |
| **Risk** | **Governmental bodies** | High investment costs that might conflict with budget constraints |  | ✓ |  | As highlighted in Section 4.1.2, the relevance of the challenges linked to high costs (C2 and C3) decreases as AM adoption level progresses, thus leading a reduction of this risk |
| **Legal & Regulatory Bodies** | Difficulty in enforcing AM-related standards, IP rights licenses |  | ✓ |  | Although the relevance of the connected challenges (C4, C6) increases as AM adoption progresses, this risk decreases as practitioners are aware of the relevance of AM-related standards and IP rights licenses |
| **HEIs & research entities** | Funding limitations for AM research | ✓ |  |  | As the focus of HEIs & research entities on R&D activities and AM research increases as AM adoption progresses, a lack of governmental support in this perspective might be perceived more |
| Funding limitation for AM curricula |  | ✓ |  | As discussed above, the development of AM curricula is required in the early stages. Even if governmental bodies will not adequately support this, the relevance of this risk decreases as AM adoption progresses as the need for AM curricula decreases (cf. Section 4.3) |
| Failure to develop an ecosystem model that benefits all actors involved |  |  | ✓ | The relevance of the corresponding challenge (C14, “Difficult ecosystem establishment”) remains stable between the two groups of practitioners |
| Misalignment between research focus and real-world military needs |  | ✓ |  | As the connection with the military industry increases as AM adoption level progresses (cf. value capture construct above), this risk is expected to decrease |
| Difficulties in determining generally optimal production process parameters, design procedures, etc. | ✓ |  |  | With the increased AM adoption, parts to be produced increase in complexity and uniqueness, increasing this risk |
| **OEMs** | IP protection issues (i.e., difficulty in safeguarding proprietary AM designs from unauthorized use). This may lead to reluctancy in participating in the ecosystem | ✓ |  |  | The relevane of the challenge C4 (“IP Issues & Data Breaches”) increases moving from “Early-Stage Adopters” to “Advanced-Stage Adopters”. Additionally, the number of parts to be produced is expected to increase as AM adoption progresses, hence increasing the risks for IP infringement. The effort of “Legal & Regulatory Bodies” in developing IP licensing agreements is hence crucial |
| Difficulty in benefiting from participating in the ecosystem |  |  | ✓ | The challenge “Difficult ecosystem establishment” (C14) remains stable in terms of relevance between the two groups of practitioners |
| Difficulties in determining generally optimal production process parameters, design procedures, etc. | ✓ |  |  | With the increased AM adoption, parts to be produced increase in complexity and uniqueness, increasing this risk |
| **AM technology & material providers** | Funding limitations for AM research | ✓ |  |  | As the focus of AM technology & material providers on R&D activities and AM research increases as AM adoption progresses, a lack of governmental support in this perspective might be perceived more. |
| Failure in carrying out successful R&D activities | ✓ |  |  | As the focus of AM technology & material providers on R&D activities and AM research increases as AM adoption progresses, this is more likely to occur in later stages |
| Difficulty in benefiting from participating in the ecosystem |  |  | ✓ | The challenge “Difficult ecosystem establishment” (C14) remains stable in terms of relevance between the two groups of practitioners |
| Difficulties in determining generally optimal production process parameters, design procedures, etc. | ✓ |  |  | With the increased AM adoption, parts to be produced increase in complexity and uniqueness, increasing this risk |
| **Defense & Military Organizations** | Lack of skilled personnel |  | ✓ |  | The relevance of the challenge “Lack of skilled personnel” decreases moving from “Early-Stage Adopters” to “Advanced-Stage Adopters” |
| Lack of support in utilizing the process and regulation adherence |  | ✓ |  | Although the relevance of the corresponding challenge (“Standardization and Certification” C6) increases moving from “Early-Stage Adopters” to “Advanced-Stage Adopters”, the risk is expected to decrease as the ecosystem actors have among their activities that of providing training and developing guidelines and identifying optimal production process parameters, design procedures, etc. |
| Reluctancy in using AM |  | ✓ |  | The relevance of the challenges “Workforce resistance” (C5) and “Lack of managerial support” (C9) decreases moving from “Early-Stage Adopters” to “Advanced-Stage Adopters” |
| High investment costs |  | ✓ |  | The relevance of the challenge “High investment costs” (C2) decreases moving from “Early-Stage Adopters” to “Advanced-Stage Adopters” |
| Dependency on few AM suppliers due to difficulty in certifying suitable suppliers and materials |  | ✓ |  | The relevance of the challenges “Lack of suppliers” (C1) and “Material limitation” (C7) does not increase moving from “Early-Stage Adopters” to “Advanced-Stage Adopters” |
| Parts with low quality | ✓ |  |  | The relevance of the corresponding challenges (C10, C11, C12, C15) increases moving from “Early-Stage Adopters” to “Advanced-Stage Adopters” as more parts will be produced as AM adoption level progresses. The development of new AM machines and of guidelines and standards might mitigate this risk, but these are risky activities |
| Risk of reduced responsiveness due to the non-optimalilty of current processes/machines | ✓ |  |  |
| Threat of IP legal battles | ✓ |  |  | The relevance of the challenge “IP Issues & Data Breaches” (C4) increases moving from “Early-Stage Adopters” to “Advanced-Stage Adopters”. The development of IP rights license agreements might mitigate this risk, but it is not an easy task |