

Linking constraints in idea generation theory with standardisation in product and service innovation

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Abstract: From the literature it is known that standards may positively impact innovation, but how? This paper focuses on the role of standards in the creativity part of the innovation process. Standards put constraints, and this might hinder creativity. Applying the theory of constraints, it is argued that the opposite can be the case: standards may stimulate creativity. Standards may set input constraints, process constraints or output constraints, and may influence innovation via different routes: the motivational route, the cognitive route and the social route. Standards can be both internal standards, defined by the company itself, and external standards. These may apply both to products and to services. Current literature tends to focus on output constraints only: by providing requirements for products or services, standards steer the creativity in the preferred direction and may trigger the development of solutions that meet the requirements. But standards may provide input and process constraints as well. In the product case this can be understood using the concepts of component commonality, platforms, modularity and postponement. For services, standards may apply to, for instance, service delivery, service results, precautions, and ethical codes for employees. But also for services modularity may apply: services can be assembled in service packages.

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Submitted: 19-09-2022

Accepted: 20-09-2022

Published: 03-10-2022

Peer review: editor review after review by jury of CEN/CENELEC Standards + Innovation Young Researcher Award

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DOI:

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Published by TU Delft OPEN on behalf of the author

Keywords: standards, standardisation, idea generation, constraints, innovation

1. Introduction

One of the major arguments of standardisation and innovation literature is that, contrary to conventional wisdom, standards do not necessarily hamper innovation and, indeed, they can actually enhance it. In this paper, we aim to further contribute to the understanding how standards can enhance idea generation. To do so, we will look at standards through the lenses of idea generation theories and we will relate them to the so-called constraints in creativity. Interesting findings in idea generation theory show that, contrary to extensive literature in idea generation (e.g., Amabile, 1996), absolute freedom and autonomy might not be the best resource for creativity and idea generation (Baker and Nelson, 2005). Instead, it is argued that some degree of constraint might actually increase creativity levels and innovation. Standards are viewed as a type of constraint (Acar et al., 2018) and, indeed, constraints can be identified in different product and service standardisation strategies. Therefore, it is interesting to examine



both the role that standards play as a constraint in product and service innovation, as well as the role of constraints in idea generation in product and service standardisation strategies. The analysis of these relationships will allow for a better and more complete understanding of why standards do not necessarily hinder innovation and might truthfully have a positive effect on innovation.

2. Constraints in idea generation theories

Constraints are any type of external imposed factor that limits creativity and/or innovation and, can take the form of deadlines, rules, design specifications, budget limits, etc. (Acar et al., 2018). Conventional wisdom and extant research have argued that constraints limit the ability to generate ideas and that they are detrimental for creativity (e.g., Amabile and Pratt, 2016), so they argue that the complete elimination of constraints is positive for creative efforts; aiming for freedom and autonomy. Nevertheless, other streams of research show that, contrary to that vision, constraints can actually increase creativity levels and favour innovation. Also, they argue that constraints help to innovate better (Acar et al., 2018; for standards, de Vries and Verhagen, 2016) and establish an inverted U-shaped relationship between constraints and creativity and innovation (see Appendix 1). This means that:

- for low levels of constraints (i.e., high levels of autonomy and freedom), creativity is low;
- for moderate levels of constraints (i.e., moderate levels of autonomy and freedom), creativity is enhanced;
- for high levels of constraints (i.e., low levels of autonomy and freedom), creativity is hindered

Moreover, in their paper they classify constraints in three different types (input, process, and output), they argue that the effects of constraints on creativity occur through three mechanisms (motivational, cognitive and social), and that there are some moderators that affect this relationship between constraints and creativity and innovation. In the following sections, these types, mechanisms and moderators will be described.

2.1. Types of constraints

Creativity and idea generation constraints can be classified into three categories. The first one, *input constraints*, refers to restrictions in the necessary resources to develop an idea and include time, money, materials, and human capital, among others. Second, *process constraints* are restrictions that determine the way (the path) to generate ideas. In other words, the formalization of the steps to follow to generate ideas. Finally, *output constraints* are restrictions that define the specifications that the end product must comply with (Acar et al., 2018).



2.2. Mechanisms and moderators

According to Acar et al., (2018), constraints impact creativity in three different ways. The first is the motivational route. In this route, the constraint can create motivation or not to innovate and generate creative ideas. The second route is the cognitive route and refers to cognitive process of idea generation, which includes opportunity identification, cognitive fixation, information search, recombination of ideas, etc. The final mechanism is the social route, which refers to the interaction between individuals, teams, and organisations in creative and innovative activities. It includes social processes such as trust, conflict, or exchange of information.

Each route presents certain moderators that determine whether the constraint shall have a positive or negative effect on idea generation. These moderators modify the aforementioned inverted U-shaped relationship by shifting it leftwards or rightwards. In the case of the motivational route, the moderators are those that shape how the constraint is perceived, i.e., whether the constraint is a source of create challenge or control. For the cognitive route, prior experience, expertise, and learnability are examples of moderators; they affect the ability to generate creative solutions. The social route is moderated by the need of social interactions and the value that they can bring (Acar et al., 2018). Lastly, radicalness of innovation moderates all three pathways, and shifts the inverted U-shaped relationship leftwards, meaning that the level of optimal constraints is lower for radical innovations than for incremental innovations.

The three different types of constraints that have been described in the previous section are affected by these mechanisms. Certain types of constraints are more affected by certain types of mechanisms than others, with evidence proving it. Nonetheless, it is important to say that the fact that there is no evidence yet about some relationships does not mean that such relationships do not exist (Acar et al., 2018). Further in the study we will speculate about some potential relationships that do not have empirical evidence hitherto in the case of standards.

See Appendix 2 for a visual representation of the interactions of the constraints and the mediating mechanisms.

2.3. Contingencies of constraints

For a deeper understanding of constraints, we can identify certain elements that can make distinctions among them. These are enforcement, malleability and timing and they also moderate the relationship between constraints and creativity and innovation (Acar et al., 2018). Enforcement refers to the incentives used to comply with the regulation, by encouraging or discouraging (e.g., incentives to renewable energy for encouraging, or taxes for CO₂ emissions for discouraging). Malleability represents the flexibility of a constraint; that is, how strongly fixated it is or, on the contrary, is somehow variable. Last, timing considers the timing in which the constraint is applied in the creative process.

These elements have not been studied in existing constraints literature. However, in this paper we are going to evaluate their status and role in the different product standardisation strategies since it can add more value to the understanding of the role of standards as constraints.



3. The relationship between constraints and standards

According to Acar et al. (2018), standards are in the output constraint category. Following the definition of de Vries (2008), standards are “approved specifications of a limited set of solutions to actual or potential matching problems” (de Vries, 2008, pp. 19). Then, since they are specifications of solutions, they determine one or more characteristics of the output and therefore behave as output constraints. These solutions can concern products, services or processes.

De Vries (2008) also classifies standards into three categories, which are basic standards, requiring standards and measurement standards. Basic standards refer to terminology standards, standards providing reference models and “standards for standards” (de Vries, 2008, pp. 19). Requiring standards include performance standards and standards that describe solutions. Requiring standards can be further categorized into interference standards, compatibility standards and quality standards. Measurement standards describe a solution for measuring. It is quite straightforward to understand basic and requiring standards as output constraints; they establish the basic definitions or features of an output, and they establish the specifications of a solution (de Vries, 2008). Hence, if we want to innovate in a particular field with basic and requiring standards being present, we have to comply with these output constraints. For the case of measurement standards it might be less obvious, but they are still output constraints. When innovating in a product or service for which certain measurement standards apply, each measurement standard acts as an output constraint for the product or service since it prescribes how to assess the extent to which requirements are met.

Standards as output constraints are considered to be both detrimental and favourable for innovation and creativity. They are deemed as detrimental because they promote uniformity and consistency (Gilson et al., 2005), which clash with innovation and creativity. On the other hand, they are argued to be favourable because they provide stable interfaces upon which to innovate and because they channel attention towards new knowledge (de Vries and Verhagen, 2016).

Limited evidence shows that standards affect creativity and innovation through the cognitive route (Acar et al., 2018; de Vries, 2021); that is, standards behaving as output constraints trigger cognitive thinking and help using intelligence to come up with innovative solutions. This route is activated and the effect of the standard (output constraint) is enhanced and larger when the individual or group subject to this restriction have expertise in the field and high learnability among others.

Standards allow to establish search boundaries and therefore reduce the cognitive load needed to search for and generate ideas (Rosso, 2014). Furthermore, in the design process, the effect of standards makes individuals to stray from the most obvious solution, known as the path-of-least-resistance (or POLR, Ward, 1994) (Moreau and Dahl, 2005). Following the POLR requires less cognitive effort, but the ideas generated tend to be based on previous experience and knowledge. Standards help in altering the conditions (the objective) of the design process, reduce the cognitive effort and therefore foster unconventional thinking.

Besides, output constraints can also trigger the motivational mechanism, on account of the fact that they can act as motivators or challengers (Acar et al., 2018). Moreover, beyond standards,



findings in literature proves that product or design requirements have a positive effect in innovation and creativity (Moreau and Dahl, 2005; Rosso, 2014).

3.1. Product standardisation, innovation, and constraints

Nevertheless, the role of constraints in standardisation does not limit to the overall concept of a standard being an output constraint in idea generation. Constraints are also visible and applicable to the different product standardisation strategies. In this paper, we will take as a basis the product standardisation strategies regarding mass customization (defined as meeting differing customer needs by offering a variety of products while maintaining economies of scale realized through the underlying unity in products as well as in the manufacturing system, Davis, 1987) presented by de Vries, Jans and Halemane (2018). These strategies are component commonality, platforms, modularity, and postponement.

Since each strategy aims for a different objective, these four strategies allow for innovation in different ways and present different types of constraints in their correspondent idea generation processes. In the following sections, the mass customization strategies will be quickly described and the role of constraints in idea generation will be discussed.

3.1.1 Component commonality

Component commonality, also known as component sharing, refers to the use of a component in different end products of the same product line (Labro, 2004). The use of a certain version of a component is used in further product generations. In component sharing we can identify both input and output constraints, depending on the point of view. A company that deploys component commonality has different components in their “input portfolio”. If that company aims to innovate, they can use these components to come up with new products and therefore we identify input constraints. They can recombine components in different ways and come up with innovative products. They can also combine existing components (input constraint) with other newly developed components. On the other hand, the company might want to innovate and create a product that has to specially include a certain component. In that sense, we can deem it as an output constraint. Moreover, the components also have output constraints since they have to be designed so that they can be used in another products.

Input constraints in component commonality behave as “limited resources” and this can trigger the cognitive route, making the individual or group engaged in innovation to come up with innovative ways of combining these resources to generate creative ideas. Input constraints can also increase motivation to overcome the “challenge of limited resources”. Nonetheless, if the input constraint is perceived negatively (a means of control or a restriction), it can be detrimental for innovation. The effect of the constraint depends on the intensity of the existing moderators. In the case of output constraints, they also trigger the cognitive path by narrowing the scope of the innovation and establishing a basis upon which to build (de Vries and Verhagen, 2016). The motivation route can also be triggered by the output constraints in component commonality and again, the exact effect depends on the intensity of the moderators.

Finally, regarding the aforementioned contingencies of constraints, in the case of component commonality, its enforcement mechanisms are strong since the use of the components as input and output constraint is desired as it means less work and effort since the component is already



designed. Moving away from the existing component would require developing a new one. The malleability is product-specific, depending on how easy or difficult it is to adjust a component. And the timing is not a variable that the company can control much. From the moment a component is designed, it can behave either as an output and input constraint. The timing can play a role in output constraints, since an output which includes a new input can only be developed (or designed) when that input has been designed.

3.1.2 Platforms

Sawnhey (1998, pp. 57) describes platforms as "collection of subsystems and interfaces that form a common structure on which a stream of derivative products can be developed and produced efficiently. They are also defined as "collection of assets which are shared by a set of products" (Robertson and Ulrich, 1998, pp. 20). These assets can be components but also processes, knowledge and people.

The role of constraints in innovations in platforms is broad, since there can be input, output and process constraints. A platform can be deemed to have input constraint in the innovation process if its approach is: "these are the elements of the platform and, considering them, innovate". An example could be to innovate in the platform itself, rather than the products, or also a new product recombining existing products of the platform. Then using the assets of the platform as input constraints could be one way to innovate. Also, if the platform sets the guidelines for interaction within the platform, we can also argue that there are process constraints (de Clercq et al., 2013). Indeed, the platform can determine standard procedures in new product development, hence incurring again in process constraints (Acar et al., 2018). Lastly, there are output constraints since the idea generated has to fit within the boundaries and specifications of the platform itself.

In the case of platforms, constraints trigger basically the cognitive rule since it tunnels attention into the platform and establishes the basis upon which new technologies or products can be built upon. Indeed, platforms, since they can connect people as well (de Vries, 2021), they can also trigger the social route.

Moving on to the contingencies of the constraints, the enforcement of the contingencies relies basically on the incentive to produce within the platform and be part of it. The malleability again is product- and platform-specific, since the constraints are more or less malleable depending on how flexible or variable are the elements of the platform that conform the constraints. For example, in the case of a process constraints that describes how the interactions among individuals have to be, the constraints will be more or less malleable depending on how intense this constraint is. The timing of the constraints is something that develops more organically rather than it is controlled by the company; it is random depending on when the innovation occurs.

3.1.3 Modularity

Modularity is defined as the assignment of functional elements of a product to the physical building blocks of the product (Ulrich and Eppinger, 2000). The purpose is to define basic physical building blocks of the product in terms of their function and their relations to the rest



of the device (de Vries et al., 2018). Then, there are clearly output constraints for the modules: they have to fulfil a function and they need to be ready to relate with other parts. The end product is also subject to output constraints since it has to use these modules as inputs, or it can combine existing modules with new modules. The interface is also an output constraint, since the different modules have to interact among them. On the other side, if the innovation approach is to use the existing modules to innovate, then there would be input constraints.

Similar to component commonality, the main trigger is the cognitive route the individual or group generating ideas needs to have knowledge and expertise about the domain (or product) that is affected by modularity. The motivational route also is followed since the modular design can spark innovativeness by challenging the individual or group engaging in innovation.

The contingencies of the constraints are also similar to those of component commonality. Enforcement mechanisms are incentives to use the modules as output constraints and therefore incur in less design costs. Malleability is again product-specific (or module-specific) and depends on how loose or strict the interaction among modules and between modules and the interface is. Finally, the timing of the constraint is again something that is more organic than controlled.

3.1.4 Postponement

Postponement is a combination of a product- and process- approach and it aims to shift the customer order decoupling point (point of differentiation) as close as possible to the customer (de Vries et al., 2018). It aims at customizing the end product as late as possible.

This strategy poses an output constraint in the idea generation process since the end product has to be able to be differentiated as late as possible in the production process. Or, from the opposite point of view, the product has to be common as long as possible in the value chain. Similarly to the other strategies, the main trigger is the cognitive path, even though the motivational path is relevant as well.

In this strategy, the timing contingency of output constraint is of special relevance. This is because the company can decide when to apply the output constraint of “commonality” of the intermediate product (i.e., at the decoupling point). The company can try to influence how long a product should be common and when to establish the decoupling point. However, it should take into account that this might affect how the motivational effects influence creativity since the constraint can be perceived then as a control rather than a challenge.

3.2. Service standardisation, innovation, and constraints

Even though at first glance standards might seem unfeasible in services due to its particular characteristics (intangibility, simultaneity, perishability, etc.), companies have provided and provide standardized services (de Vries and Wiegmann, 2017). Their span is very broad and can apply to service delivery, service result, precautions, ethical code of employees, etc. As in the case of products, standards act as output constraints in the innovation process since they specify requirements for a certain solution. Nevertheless, similarly to product standardisation strategies of component commonality or modularity, services can also be assembled in service



packages, and then the service standards that apply to the services that conform the service package constitute input constraints. Finally, any standard applying to the service package would also be an output constraint.

Since they are output and input constraints, the mechanisms that standards trigger are the cognitive and the motivational. Standards can trigger service innovation by leading to new service development (a new service that fulfils the same need) or by stimulating companies to innovate in their current services (de Vries and Wiegmann, 2017). **4. Discussion**

Although many people in the R&I community do not believe that standards can have a beneficial impact on innovation, standardisation and innovation literature shows that standards do not only necessarily negatively impact innovation, but also it can enhance it (de Vries and Verhagen, 2016; Hawkins, Blind and Page, 2017). This paper further contributes to demonstrate that standards and standardisation can enhance innovation and make innovation more effective. The role of standards in innovation can be related to the role of constraints in creativity (Acar et al., 2018), so relationships between these two streams of literature were established.

Idea generation literature suggests an inverted U-shaped relationship of constraints and creativity in which moderate levels of constraint can help creativity, accounting as well for the intensity of the moderators of the pathways and the characteristics of the constraint contingencies (Acar et al., 2018). On the other hand, findings in standardisation and innovation literature suggest that an excessive amount of standards, standardisation that occurs too early and standardisation that starts too late are expected to hinder innovation (de Vries, 2021). Furthermore, narrow and prescriptive standards also can negatively impact innovation (de Vries and Wiegmann, 2017).

Related to these findings, we can argue that having too many standards induces too many constraints and therefore the location of this situation in the inverted U-shape would be to its far right, resulting in poor results in creativity. Over-early standardisation and standardisation that takes place too late translate into an inadequate timing of the output constraint. While over-early standardisation translates into high level of constraint and as a result hinders innovation, late standardisation translates into high level of autonomy, hampering innovation as well but through the opposite way. Last, narrow and prescriptive standards would translate into excessive constraints and that would place this situation to the far-right part of the curve.

From this, we derive that the timing of the constraint is important. We have seen when to apply constraints, but we should also pay attention to when to apply freedom and relax constraints, that is, when to relax standards. According to Blind and Gauch (2009), freedom should be applied in standards when there is “lock-in”, or in other words, when a solution is frozen by standards.

This finding can be related also to the product standardisation strategies previously discussed. When certain components, modules, interfaces or platforms are locking in or freezing solutions, companies should apply freedom and autonomy to keep innovating and disregard these standardisation strategies as output or input constraints.

Staying in product standardisation strategies, in their paper, de Vries, Jans and Halemane (2018) argue that the decision on whether or not to choose a mass customization strategy as well as which one to choose, should balance the needs of the involved stakeholders, i.e., consumers and manufacturers. For manufacturers, they argue that there should be a coordinative effort



among top management, R&D, marketing, production, purchasing, sales and after-sales services, to understand and choose which strategy best suits them. Whether or not this coordinative effort and discussion should include the company's approach to innovation and idea generation is unclear in the paper. Therefore, in this paper we argue that the approach to idea generation and creativity should be included in these discussions. Companies should evaluate which kind of constraints can be more useful to them in idea generation, and each mass customization strategy presents different ones. Taking into account their offerings, their capabilities and their resources, they should decide which type of product standardisation strategy they should pursue.

Lastly, for the case of standardisation services, we see that similarly to products, services can be standardized but their particular characteristics also make that standards can be applied to a wide span of activities and that they can, as well as in products, foster innovation. Standards can also be applied to service packages and constraints in these packages can also enhance innovation.

5. Conclusion

This paper further contributes to understand the effects that standards and standardisation have on innovation and creativity, and it does so by looking at this topic through the lenses of idea generation theory – in particular, constraints. We discussed that it is not only relevant the amount of standards that are applied, but also their nature and their particular characteristics. Therefore, the amount and intensity of standards have an inverted U-shaped relationship with creativity and innovation. In addition to that, we also examined the role that constraints can have in innovation within product standardisation strategies and service standardisation.

This relationship between standards as constraints and creativity and innovation is helpful for businesses, academics, and policy makers since it gives them further understanding of how their policies in standardisation can affect innovation. The latest version of the Oslo Manual (OECD / Eurostat, 2018) points at standardization as an instrument to stimulate innovation, this essay confirms this by showing how innovation can also stimulate the idea generation part of it. Second, it is helpful for companies because, when following product standardisation strategies, they can manage the constraints of their design and production process which will eventually lead them to attain higher or lower levels of innovation. Hence, this is something they should take into consideration and therefore adjust the intensity of the constraints according to their objectives and needs.

Acknowledgements

This paper was written as an essay assignment in the elective course Standardisation and Innovation management taught by Prof. Henk de Vries, part of the Master programme Management of Innovation at the Rotterdam School of Management, Erasmus University.





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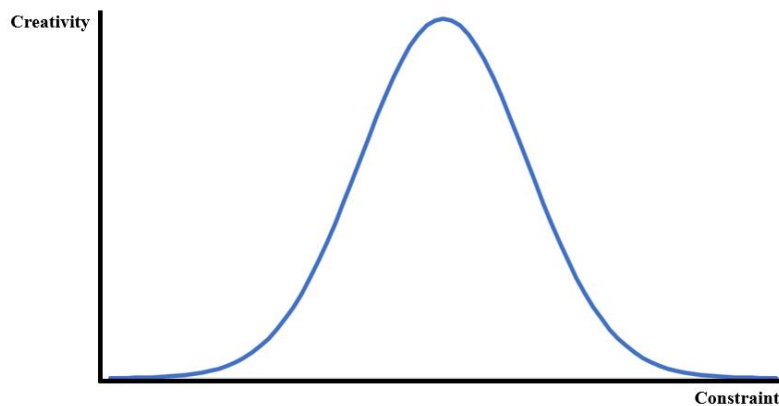


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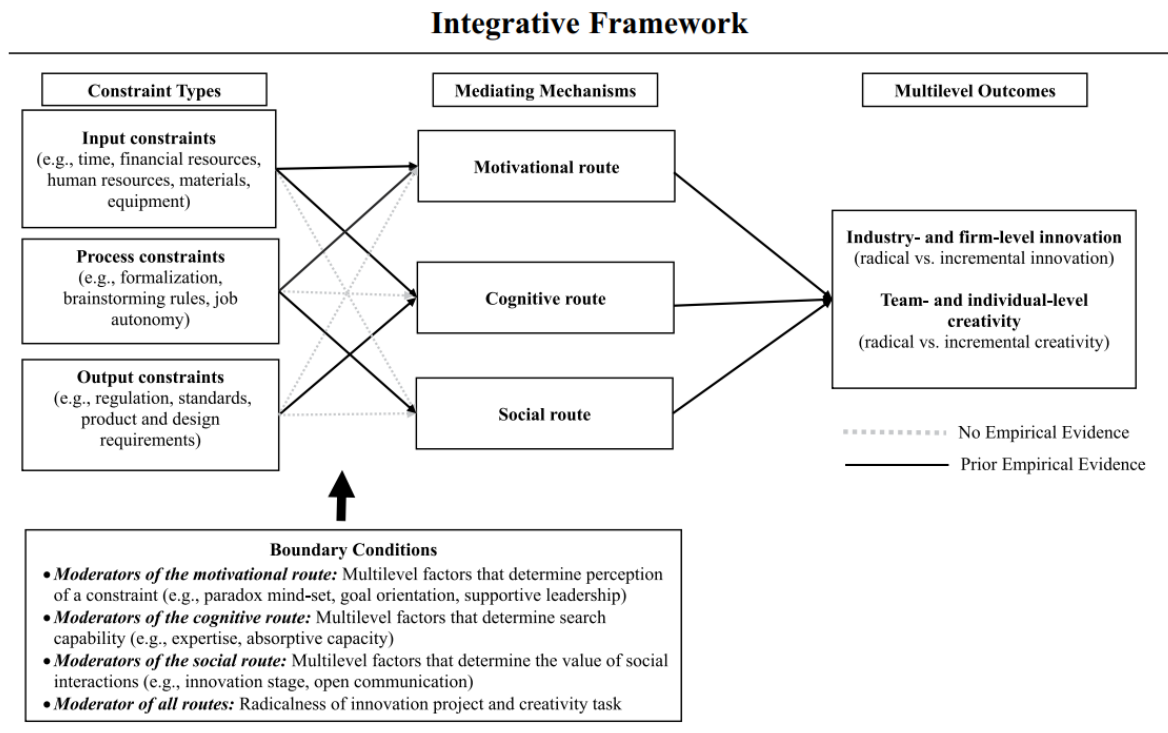
Appendices

Appendix 1 – Relationship between creativity and constraint



Source: compilation based on information by Acar, O. A., Tarakci, M., & van Knippenberg, D. (2018).

Appendix 2 – Constraints integrative framework



Source: Acar, O. A., Tarakci, M., & van Knippenberg, D. (2018). Creativity and innovation under constraints: A cross-disciplinary integrative review. *Journal of Management*, 45(1), 96-121