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A Comprehensive Framework for the Analysis of Industry 4.0 Value Domains

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Abstract: Industry 4.0 aims to ensure the future competitiveness of the manufacturing industry by providing Companies with the ability to react to rapid product changes and disturbances, efficiently and reliably, through re-configurability. In this paper, we explore the value creation process within Industry 4.0, with special emphasis on its relationship with mass customization and the sustainability issue. Based on the identified research gaps and opportunities derived from a literature review of relevant concepts, we propose the development of the Customer-Product-Process-Resource (CPPR) 4.0, a comprehensive framework that puts the value proposition-creation-capture cycle proper of an Industry 4.0 environment, in the context of a manufacturing organization's customer-product-process-resources views. The usefulness of the proposed framework is exemplified by using it to derive system dynamics model of the mass customization paradigm. A discussion of the managerial implications of the obtained results for both the sustainability and the case of Small-to-Medium Enterprises (SMEs) is offered at the end of the paper.

Keywords: industry 4.0; manufacturing efficiency; mass customization; value creation; sustainability; system dynamics

1. Introduction

Global dynamic competition—a result of always increasing customer demands—impose a series of business challenges:

- To operate with high levels of flexibility, efficiency and adaptability in the face of product and process complexity [1].
- To fast develop, design, and manufacture high quality, low cost, smart, mass customized products [2,3], at a reasonable cost and with reduced energy and resources consumption [4].
- To use virtual and physical structures that allow the management of the whole value-chain in an agile and responsive manner [5].

These challenges require companies to be smarter and more efficient (in order to increase their operational effectiveness) and to develop new business models [6]. In this scenario, the business enterprises' survival demands the ability to react (efficiently and reliably) to rapid product changes and disturbances through re-configurability [7], through the intensive use of automation, computer systems and software [8]. These are the main features related to Industry 4.0, a concept that is becoming very popular among organizations [9], especially for its implications for the sustainability of an organizations [10]. Industry 4.0 deals with the real time availability of all relevant information involved in the value creation process and the interconnection between human beings and machines in

a cyber-physical system [11–13]. This is done by combining manufacturing, automation, information, computing, communication, and control technologies, in order to establish an interconnected industrial value creation process [14,15]. Appendix A presents a brief review of some other initiatives related to the concept of Industry 4.0, with the idea of providing the reader with a way to contrast the pros and cons of the Industry 4.0 initiative. The key elements behind the idea of Industry 4.0 can be identified as follows [2,16,17]:

- (a) the optimization of the value chains; that is, the horizontal integration of products and stakeholders.
- (b) the implementation of a virtual network of autonomous, self-controlling, self-configuring, knowledge-based, sensor-equipped, manufacturing resources.
- (c) the interchange of data in and between the different phases of a product life cycle.

The purpose is achieving high levels of stability, performance, reliability, robustness, and efficiency of the physical transformation systems. This implies giving the customer the constant opportunity to become part of the value creation process through the development of tailored services [17], requiring not only the grouping together of companies and value creation functions [18–20] but also the development of new value creation mechanisms, that is, new business models [16,21]. Moreover, Industry 4.0's goal is sustainable success in a mass customization market [22], where customers increase variant diversity [23] designed to their individual specifications [16,24] and without paying a high price premium [25]. Within this context, the future of an enterprise competing within an Industry 4.0, mass customization environment, depends on their sustainability, where the latter can only be achieved by the manufacturing efficiency of the smart factory-based Industry 4.0 transforming processes [16,26,27]. For this reason, the next section reviews the structural elements that influence it (manufacturing performance), as well as the relationship between sustainability, Industry 4.0 and value creation. Derived from this literature review, we proceed to define the research features, that is: (1) to identify the research gaps and opportunities; (2) to enunciate the research proposal (3) to establish the proposed research methodology; and (4) to highlight the research originality, usefulness and contributions.

2. Literature Review

2.1. Sustainability & Industry 4.0

Sustainability has been often linked with Industry 4.0. References [28–30] review opportunities in Industry 4.0 for achieving sustainability, while References [31,32] consider that Industry 4.0 has clear implications for sustainability in organizations. When analyzing the pillars of Industry 4.0, we find that, regarding the use of CPS-based, smart manufacturing systems, Reference [33] mentions sustainability as one of the three main requirements of a smart factory. Reference [34] contends that a smart factory would help implement the sustainable production mode to cope with global challenges. Reference [35] presents sustainability as one of six pillars considered to be important in setting up smart facilities, upon which an Industry 4.0 environment is based. References [36,37], and [38] state that a promise of Industry 4.0—through the use of the so-called smart manufacturing systems—is that it will make it possible to achieve higher agility, productivity, and sustainability levels. Regarding the use of Internet of Things (IoT) and Big Data, References [39–41], and [42] discuss the importance that Big Data Analytics has in supply chain sustainability. The introduction of the internet of things (IoT) promotes innovation, customization, knowledge sharing and sustainability in a global context, according to References [43,44]. Big data in conjunction with IoT enables cleaner [45] and more sustainable production [41]. Regarding the use of Virtual Reality (VR) and Augmented Reality (AR), they can lead to sustainability and better training and knowledge [46]. Regarding the use of a cloud manufacturing platform, the use of a cloud platform by Industry 4.0 allows the intelligent management of the shared resources and services required to carry out an efficient collaborative production and, with this, the achievement of industrial benefits such as lower production costs and high levels of productivity and sustainability [45].

2.2. Sustainability & Value Creation

The value and sustainability of a business is determined by its revenue model, which answers the question of how a company earns money [47]. In fact, Reference [48] considers sustainability to be one of the elements of a business model. Now, according to Reference [49], sustainability is a business feature of Industry 4.0. However, Industry 4.0 does not explicitly tackle sustainability issues and only does it when its benefits also have an economic benefit [17]. On the other hand, the sustainability issue and its link with Industry 4.0 has been discussed from a business modelling perspective in References [28,29]. Reference [50] suggests there is a need to develop innovative business models that guarantee sustainability. As early as 2004, Reference [47] mentioned that having a business model ontology to hand that describes the essential building blocks and their relationships would make it easier for managers to design a sustainable business model. In this same context, Reference [17] reviews sustainable business models in Industry 4.0, understanding this last as the “how to run a company” in a sustainable way. The work of Reference [30] identifies opportunities for Industry 4.0 that can result in sustainable business models but it does not explicitly explain how this is achieved. Reference [51] reports that there is no qualitative assessment of the contribution of Industry 4.0 to sustainable value creation. Reference [17] proposes a research agenda which includes the development of sustainable value propositions for Industry 4.0 and the development of cost-benefit analysis/revenue models for Industry 4.0 supporting sustainability.

2.3. Sustainability & Manufacturing Efficiency

According to Reference [52], there is a need to take into account the strategic level and operational levels of a manufacturing organization, as both of them are interdependent: the strategic level decision-making has a deep impact at the operational level and the correct management of the operational level has a big impact on the efficiency of the strategic level. This efficiency has to do with the better use of resources by the transformation process [17]. So, even though strategic issues are important for achieving responsiveness to market changes, they are not sufficient without achieving responsiveness at the operational level. The Customer-Product-Process-Resource (CPPR) framework—proposed by Reference [53], Figure 1—allows the addressing of these through a set of within-and-among alignment conditions necessary for linking the strategic and operational levels [54], expressed in terms of configuration attributes that, in turn, allows the establishment of the documents that promote proper manufacturing execution and, with this, efficient performance [55]. If we consider that the strategic-operational alignment factor affects the performance of a manufacturing organization [56], then it becomes necessary to take it into account in order to reach high levels of sustainability (by avoiding poor efficiency in both managerial and transformation processes).

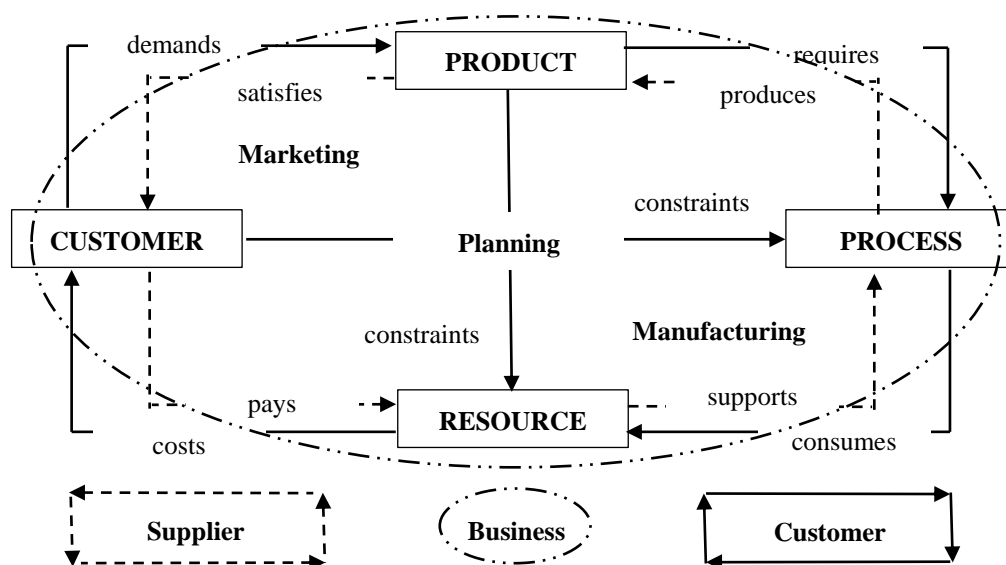


Figure 1. The Customer-Product-Process-Resource (CPPR) framework [53].

3. Research Features

Table 1 summarizes the contribution of the authors presented in this literature review. From the previous presented literature review we can conclude that:

- (1) Sustainability is understood as a potential benefit of the implementation of the Industry 4.0 paradigm, the use of high efficiency systems being its main sustainability feature, according to Reference [57]. From here comes the need to establish the achievement of sustainability in the context of manufacturing efficiency.
- (2) Sustainability is a must-element of the business models used by Industry 4.0. From here comes the need to develop business models that are sustainable.

Table 1. Literature review summary table.

Topic Addressed: Sustainability and ...	References
Industry 4.0 links, opportunities, and implications	[28–32]
Smart Manufacturing	[33–38]
Big Data Analytics	[39–45]
Virtual/Augmented Reality	[45,46]
Business economic benefits	[47–49]
Business Models	[17,28–30,47,50–52]
Manufacturing efficiency	[53–56]

In order to address these identified research gaps, we state our research objective to be the development of a framework that establishes the value proposal-creation-capture cycle in the context of the strategic/operational levels that affect overall manufacturing efficiency within a manufacturing organization. The theoretical foundation of the proposed framework (referred to as the CPPR 4.0 throughout the rest of the document as) was established following a approach similar to the one used in References [58–60] when building a reference model—where a “best of breed” approach was followed by combining and integrating academia initiatives, identified via the analysis of existing literature. This required the review of the literature in the area of: (1) business models; and (2) value creation within an Industry 4.0 environment (referred to as value creation 4.0 throughout the rest of the document), and the mapping of the findings into the CPPR framework. The originality of the work is on the approach followed, where concepts that have never been put together

before are combined and formally integrated [61,62]. The usefulness of the proposed framework is demonstrated by using it to derive a system dynamics model of the mass customization paradigm (within an Industry 4.0 environment). The original contributions of the present paper are the proposed framework and the derived system dynamics model.

4. Theory Foundation of the CPPR 4.0

4.1. Business Models

According to Reference [47], a business model is a representation of how a company buys and sells goods and services and earns money. They answer questions like, who are customers, what to offer them, and how to operate to create value in profitable/sustainable way [1]. Authors of References [63–67] propose three interconnected value domains of a business model: Value proposition (reason why customers turn to one company over another), Value creation (resources, capabilities, and processes required to deliver the value proposition), and Value capturing (cost structure and revenue formula, which defines the profitability and economical sustainability of the business enterprise). As there is as an enormous value to management to have a software-based version of a business model, References [47,68,69] introduced its Business Model Canvas (BMC), composed of nine elements divided into four categories: Product (what? or value proposition domain), Customer interface (who? or value creation domain), Infrastructure (how? or value creation domain), and Financials (value capturing domain). The reader is encouraged to consult these references for a more detailed explanation.

4.2. Value Domains

According to Reference [47], value domains are the interconnected value-related elements of a business model, namely value proposition, creation, and capturing. It has been stated that business enterprises compete against each other's through their value propositions [70], where their business models must change its view its focus from "what to offer" to "what value the offer brings for the customer" [71]. Now, the primary function of any business enterprise is the creation (and maintain) of value [72], something pivotal for firm survival [19], where traditionally it has been considered a financial measure [73], in the sense that product A creates more value than product B, if it has a lower price, provides more benefit, satisfaction, and/or a better experience [74]. Finally, a firm's survival on the long term requires not only the value creation but also value capturing/appropriation [75]. In this context, References [20,76–79], and [80] mention four factors that create value for a product, service, or combination of both: Product (what should be produced/offered?), Process (how should it be produced?), Equipment (by what means should it be produced?), and People & Organization (when/where should it be produced and who should produce, supervise and manage?).

4.3. Business Models/Value Creation 4.0

Within the context of this document, we define the term "value creation 4.0" as the value creation process within an Industry 4.0 context. According to References [81,82], in order for Industry 4.0 to have implications for industrial core value creation, it is necessary to develop (1) new value creation business models [81], and (2) a platform-based cooperation that promotes the personalized service/product offer in real time. These new business models emerging from the integration of technological innovations [13], are expected to have a focus on the creation of value from data generated data from the end-users (customers) [63,83,84], so they need to be designed around the business logic of highly customized and differentiated, well-synchronized product-service combinations [20,84,85]. The more cooperative environment provided by Industry 4.0 is transforming the current methods of value creation [13], where the "anywhere, anytime" ability to gather information through all the product lifecycle allows value creation not only from product selling/service offering a service but also from exploiting the available data [17]. In this context, the four "P" elements of value creation mentioned by Reference [20] can be characterized in terms of smart customers, products, processes, and resources [86]. According

to Reference [16], these four elements are the basis of a smart factory, defined by Reference [86], as a flexible, intelligent, and highly optimized (in terms of waste, defect, and, downtime) productive manufacturing system where people, systems and objects communicate with each other, through the IoT. This is the type of manufacturing environment necessary to address the global economic mass customization pressures [17], where the ultimate objective is the real time coordination and optimization of the production stages, so customized products can be manufactured at the costs of mass production [56,87].

4.4. Mapping Value Domains into the CPPR Framework

Based on the identified similarities between Osterwalder's Business Model Canvas [68], Seliger's value creation factors [76] and Stocka's value creation elements [51], we propose representing the value domain in terms of representative elements, main goals, and building blocks (Table 2, the first original contribution of this research effort). Further on, based on the stated features of the CPPR framework, in this research document we propose the development of the CPPR 4.0 framework, which reflects the particular features of the Industry 4.0 value domains (established in Table 2) and that can be used to address the challenges of both the strategic and operational goals:

- Strategic level; to establish the conditions under which the whole cycle of value creation—that is, what should be offered, when/where/how/with what/by whom should it be produced and how to profit from what is to be offered—can take place (understanding the value creation process in terms of a value chain).
- Operational level; to establish the conditions under which self-awareness, self-negotiating, and self-improving capabilities of products, processes, and resources respectively, can take place in terms of an information reference model.

Figure 2 shows our proposal of the CPPR 4.0 framework (the first original contribution of this research effort). It contains the particular features of the Industry 4.0 value domains (established in Table 2), distributed into four value domains sectors (one for value proposition, one for value capturing, and two for value creation). Now, regarding these sectors, the following must be mentioned:

- Value proposition sector; three tools for building value propositions are Barne's Value Proposition Builder [70], Osterwalder's Value Proposition Canvas [68], and Wildevuur's People Value Canvas [88].
- Value creation sector; describes the way value is created, and according to Reference [89] this can take the form of value chains (where value is created by transforming input factors into products/services), value shops (where value is created by solving a customer problem), and value networks (where value is created by mediating and coordinating relationships between network of people).
- Value capturing sector; according to Reference [75], value capturing can be performed in three forms: monetary (i.e., increase the per unit net profit by matching the price with the value offering), relational (i.e., increase customer retention, use the network partners' fullest potential) and learning (i.e., co-create knowledge through collaboration with external stakeholder).

As this research effort is a work in progress, we are interested in presenting the usefulness of the CPPR 4.0 framework, as a first step, at the strategic level. More specifically, we are interested in showing how this last can be used to develop a system dynamics model of the mass customization paradigm.

Table 2. Industry 4.0 value domains: representative elements, goals, and building blocks.

Value Domain	Question	Element	Strategic Level			Operational Level		
			Description	Main Goal	Building Blocks	Description	Main Goal	Building Blocks
Value capture	“How to profit from what is to be produced/offered?”	Customer	Money generated based on the value creation	To profit in a sustainable way from value creation	Cost structure Revenue model	customers’ needs/behaviors real-time analysis	to provide sustainable products/services	customers’ access to value creation networks
Value proposition	“What should be produced/offered?”	Product/ Service	Products/Services offered to the market	To obtain solutions that create value	Value proposition	self-aware products	autonomous decision-making	embedded internet-communication sensors/microchips
Value creation	“When/Where/How should it be produced/offered?”	Process	Processes/Resources required for value delivery	To promote/facilitate the value creation flow	Internal processes External processes	self-negotiating customer orders	decentralized decision-making	autonomous operations optimization systems
	“With what/By whom should it be produced/offered?”	Resource		To enhance the capabilities required to support the value creation flow	Value configuration Partnerships Capability	self-improving resources	intelligent decision-making	self-organization and adaptiveness abilities/capabilities

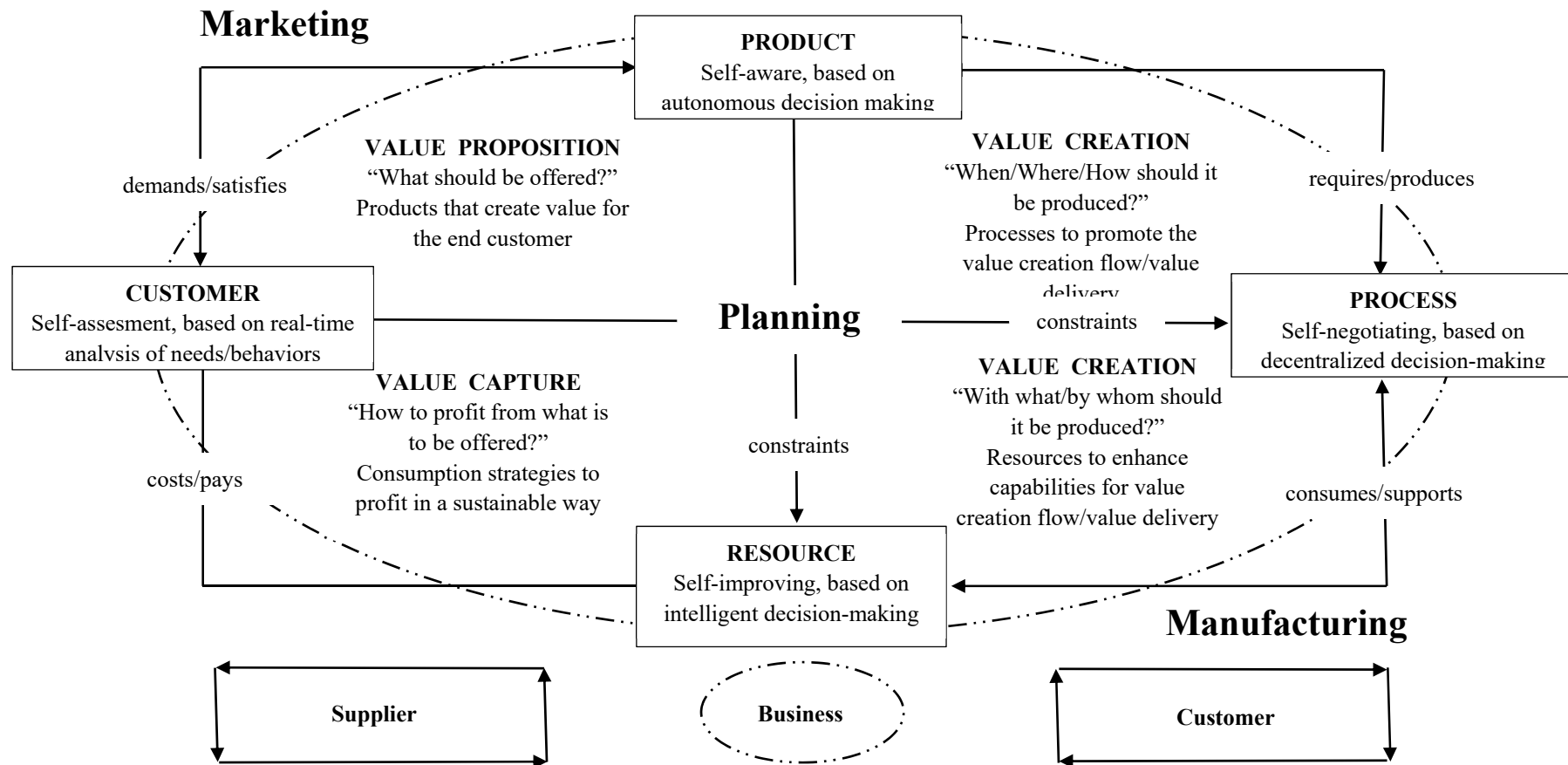


Figure 2. The CPPR 4.0 framework.

4.5. Practical Use of the CPPR 4.0

The CPPR configuration attributes (see Reference [56] for more details) were mapped into the context of the mass customization paradigm (Table 3). From here, a casual loop diagram (CLD) was derived (Figure 3) using the following reasoning:

- Relationship #1: as the level of customization increases, the level of the product's complexity increases.
- Relationship #2: as the level of customization increases, the level of OW/OQ increases.
- Relationship #3: as the level of OW/OQ increases, the level of production variety increases.
- Relationship #4: as the level of product's complexity increases, the level of production volume decreases.
- Relationship #5: as the level of system's reconfiguration increases, the level of production volume increases.
- Relationship #6: as the level of system's reconfiguration increases, the level of production variety increases.
- Relationship #7: as the level of production variety increases, the level of components/raw materials increases.
- Relationship #8 and #9: as the level of technification and level of labor skill increase, the level of the system's reconfiguration increases.

Table 3. Mass customization configuration attributes.

Element #	CPPR Context	Mass Customization Context
1	Level of required customer feedback	Level of customization
2	OW/OQ ratio	Level of OW/OQ
3	Number of operations/components	Level of product's complexity
4	Level of production volume	Level of production volume
5	Level of product variety	Level of production variety
6	Level of technology specialization	Level of technification
7	Level of labor skills	Level of labor skill
8	Level of process flexibility	Level of system's reconfiguration
9	Level of raw material requirements	Level of components/raw materials

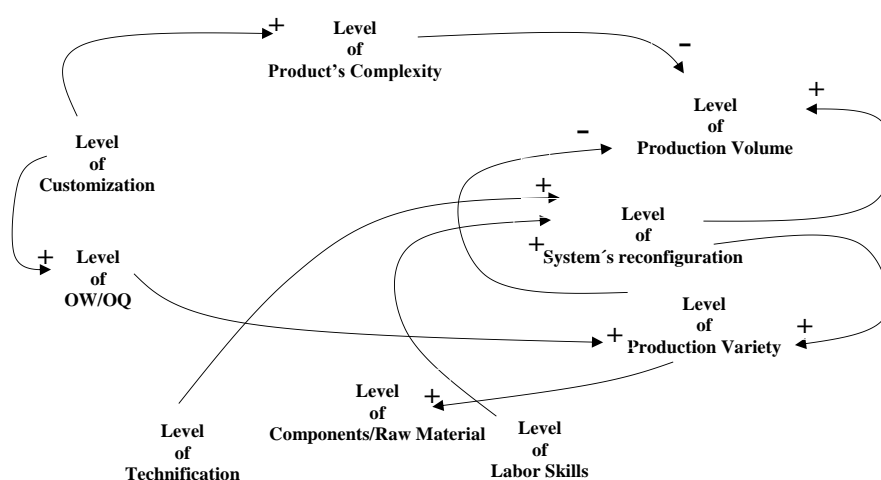


Figure 3. Mass customization paradigm casual loop diagram (CLD).

The next step taken was the development of a system dynamics model (Figure 4) using the Stella software (www.iseesystems.com). The purpose of the system dynamics model is the analysis of the Production Volume that can be achieved for a combination of different Level of Customization and Level of System's Reconfiguration values.

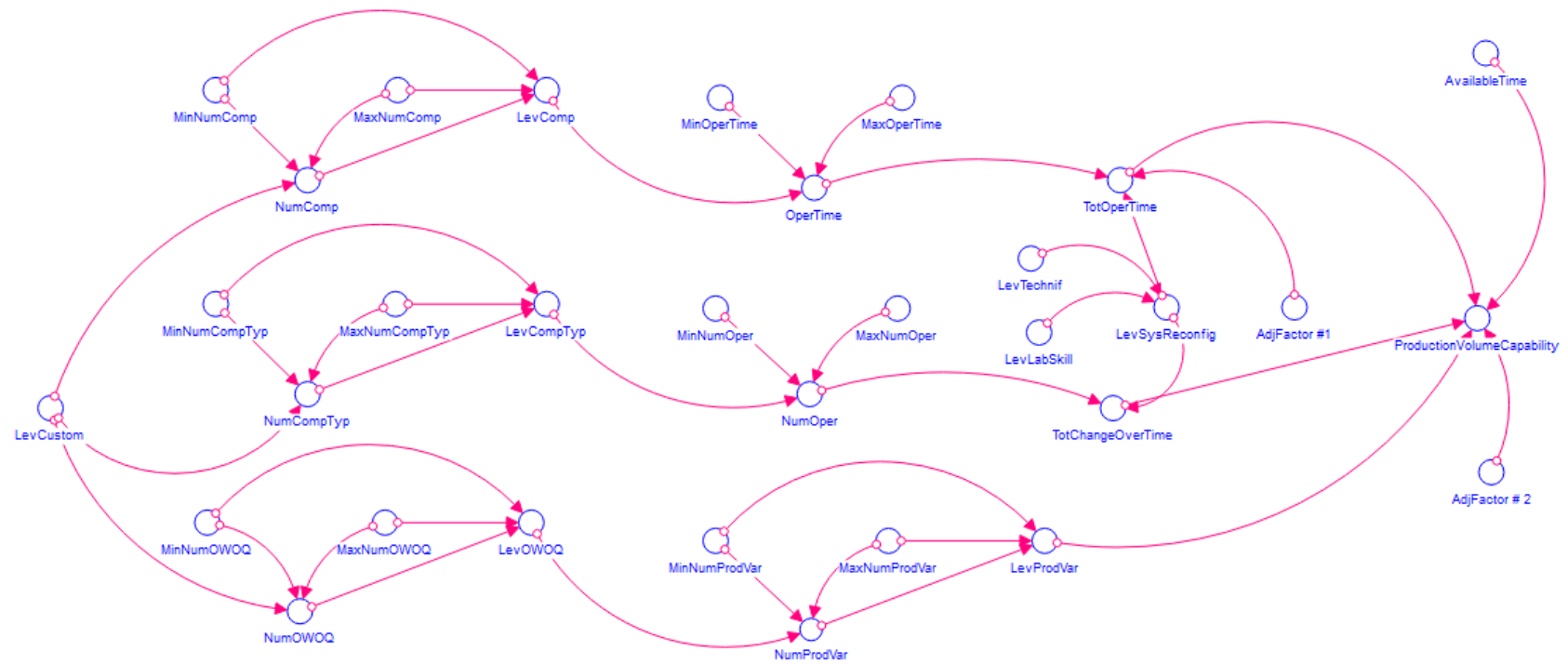


Figure 4. Stella Model of the CPPR 4.0 casual loop diagram.

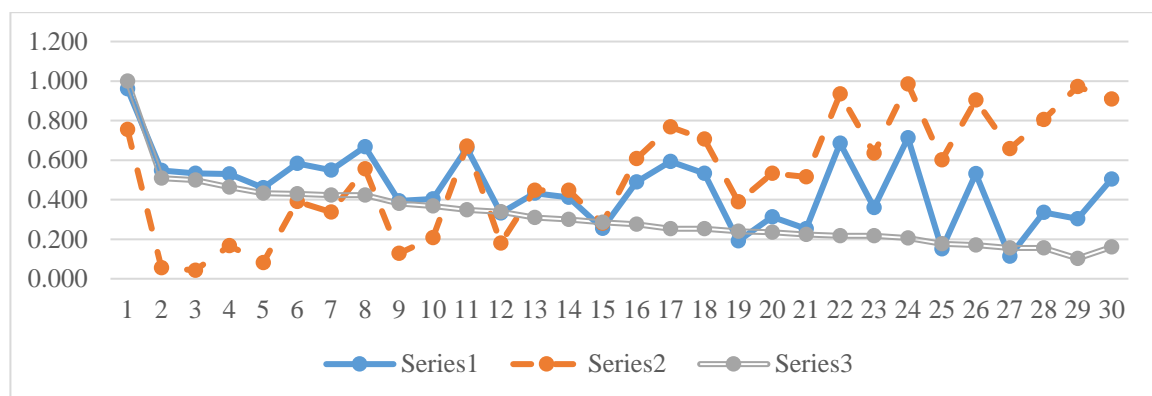
Appendix B explains the logic behind the equations used in this model. Five different runs were conducted for the duration of thirty periods in each case. Figure 5a–e present the results obtained: Series 1 (solid line) reflects the Level of System Reconfiguration; Series 2 (dashed line), the Level of Customization; and Series 3 (double line), the normalized Production Volume values. In each of these figures, the normalized Production Volume values are organized from higher to lower values. An analysis of Figure 5a–e reveals the following:

- For Figure 5a; the Level of System Reconfiguration trend line is over the Level of Customization trend line for the first ten simulation runs (with a slow close of the gap). Then, both trend lines intersect four times, in the span of four simulation runs (11–15). After this, the opposite situation takes place. This results in a Production Volume trend line with a slope of $[0.5/(30 - 2)] = 0.017$
- For Figure 5b: the Level of System Reconfiguration trend line is over the Level of Customization trend line for the first eleven simulation runs (with a sudden close of the gap). Then, both trend lines intersect six times, in the span of ten simulation runs (11–21). After this, the opposite situation takes place. This results in a Production Volume trend line with a slope of $[1.0/(30 - 1)] = 0.034$
- For Figure 5c: the Level of System Reconfiguration trend line is over the Level of Customization trend line for the first five simulation runs (with a sudden close of the gap). Then, both trend lines intersect five times in the span of ten simulation runs (5–15). After this, the opposite situation takes place. This results in a Production Volume trend line with a slope of $[0.7/(30 - 3)] = 0.025$
- For Figure 5d: the Level of System Reconfiguration trend line is over the Level of Customization trend line for the first nine simulation runs (with a slow close of the gap). Then, both trend lines intersect four times in the span of nine simulation runs (9–18). After this, the opposite situation takes place. This results in a Production Volume trend line with a slope of $[0.4/(30 - 3)] = 0.014$
- For Figure 5e: the Level of System Reconfiguration trend line is over the Level of Customization trend line for the first eight simulation runs (with a sudden close of the gap). Then, both trend lines intersect four times in the span of ten simulation runs (8–18). After this, the opposite situation takes place. This results in a Production Volume trend line with a slope of $[0.5/(30 - 4)] = 0.019$

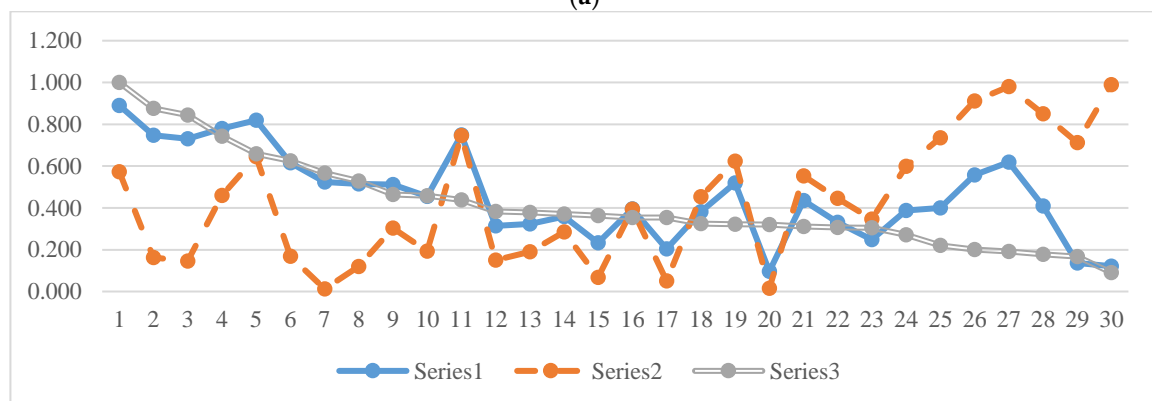
A summary of these results is presented in Table 4, where each row represents the range of differences (Δ_1) between the values of Level of System Reconfiguration and the Level of Customization, and each column represents the range of decrease (Δ_2) in the normalized Production Volume value. From this table, we observe the following:

- (1) The Δ_1 which impacts the most Δ_2 (that is, the highest value in each column), starts decreasing until Δ_1 becomes negative, when it starts increasing again (i.e., for $\Delta_2 = 1.00 - 0.5$ corresponds $\Delta_1 = 0.6 - 0.4$, decreasing to $\Delta_1 = 0.2 - 0.0$ for $\Delta_2 = 0.38 - 0.30$, only to increase again to $\Delta_1 = -0.4 - -0.6$ for $\Delta_2 = 0.16 \rightarrow 0.12$).
- (2) The impact of Δ_1 has on Δ_2 is not symmetrical, i.e., the impact of $\Delta_1 = 0.6 - 0.4$ is $\Delta_2 = 1.00 - 0.5$ (50%), where the impact of $\Delta_1 = -0.4 - -0.6$ is $\Delta_2 = 0.16 - 0.12$ (4%).

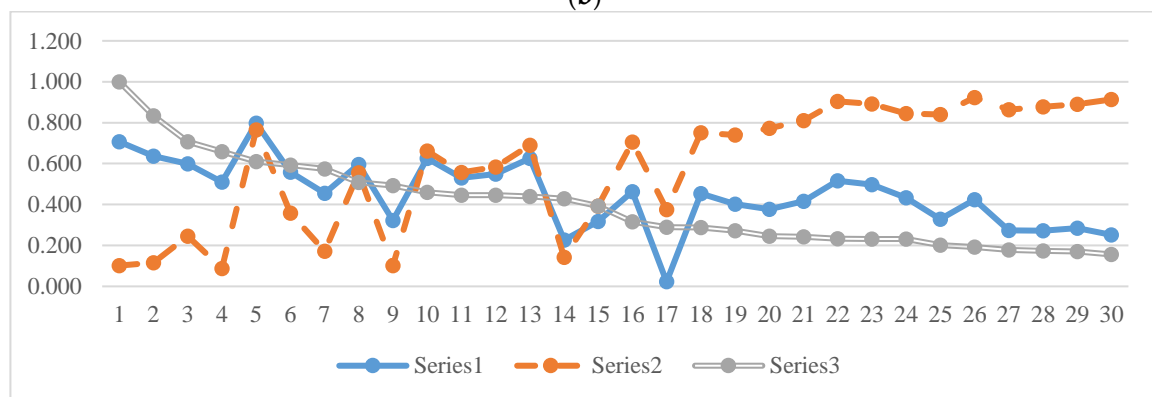
In other words, these results suggest that the impact of the Level of System Reconfiguration has on the Production Volume is bigger than the impact the Level of Customization has. In a context where Industry 4.0 only tackles sustainability issues when the latter has an economic benefit [17], these results support the idea that high levels of sustainability—through a higher productivity—can be achieved by investing in better technology without sacrificing the customers' preferences, one step further towards the development of a sustainable value proposition.



(a)



(b)



(c)

Figure 5. Cont.

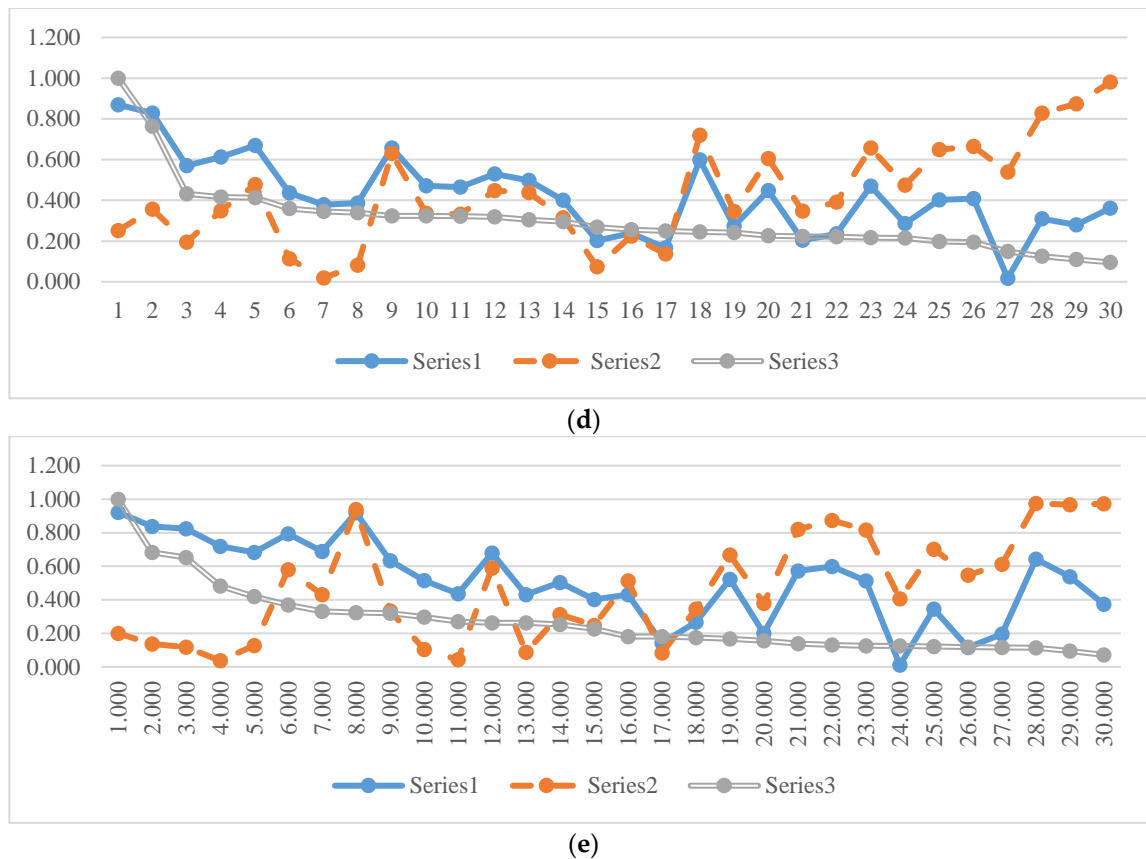


Figure 5. (a) Run # 1; (b) Run # 2; (c) Run # 3; (d) Run # 4; (e) Run # 5.

Table 4. Impact of the Level of System Reconfiguration and Level of Customization on the normalized Production Volume values (the bolded percentage within each Δ_2 column identify the highest Δ_1 interval).

Δ_1	Δ_2					
	1.00 – 0.5 (50%)	0.5 – 0.38 (12%)	0.38 – 0.30 (8%)	0.30 – 0.24 (6%)	0.24 – 0.16 (8%)	0.16 – 0.12 (4%)
0.8 → 0.6	24%					
0.6 → 0.4	32%	8%				
0.4 → 0.2	28%	56%	8%			
0.2 → 0.0	12%	28%	60%	24%		
0.0 → -0.2	4%	8%	32%	52%	28%	
-0.2 → -0.4				24%	60%	20%
-0.4 → -0.6					12%	52%
-0.6 → -0.8						28%

4.6. Managerial Implications for Small-to-Medium Enterprises (SMEs)

The Small-to-Medium enterprises' (SMEs) impact on value creation and their importance for the overall economy is a topic that has been reported frequently in the literature. SMEs are considered a backbone of the economy because of their strong position as employers [1]. They play an important role in the overall network of industrial value creation: in the European Union, they represent over 99.6% of all companies (in the case of Germany, 95%); employ between 50 and 70% of all European full time equivalents; generate a gross value added share that encompasses about 50% of the European economy [15]. Within this scenario, there is a lack of fundamental knowledge about how SMEs could

successfully participate in an Industry 4.0 environment, especially when dealing with some of the following situations:

- They may have some trouble implementing new technologies and also in modifying and adapting their business models [1].
- It is not easy for them to implement an Industry 4.0 strategy as it is difficult to join a value chain using standards and norms different from ones they currently use [90].
- They struggle to obtain the resources/knowledge required to establish the new value creation business models required to successfully implement Industry 4.0 [15].
- They have the common perception that, due to their limited capital availability and lack of expertise, advanced automation is reserved to big industrial players, which results in an adoption lethargy [91].
- They struggle with adopting and implementing Industry 4.0 solutions, as there is a lack of awareness of the link between business and technological worlds on the strategic and tactical levels within the company [92].

It is our belief that the proposed CPPR 4.0 framework could be used as a blueprint to derive a sustainable value creation business model that combines the features of SMEs and the mass customization paradigm and which takes into account the link of the strategic and tactical levels of the organization. For example, a discrete-event simulation version of the system dynamics model could be developed and used as a what-if scenario testing tool, so the proper balance between capital investment and sustainable profitability can be assessed.

5. Conclusions and Future Research

International global dynamic competition imposes a series of challenges on business enterprises. These challenges require companies to mature into something smarter and more efficient and to develop new business models. The main features related to the Industry 4.0 concept—which is becoming much popular among manufacturing organizations—are regarded to be the response to the challenges of this current global competition. Within this context, new value creation business models are needed, based on the integration of technological innovations that provide the cooperative environments necessary to promote value-creation, which does not only come from selling the product/offering a service itself, but also from exploiting the available data. In this research document, we introduced the CPPR 4.0 framework, which distributes the value proposition–capture–creation cycle of an Industry environment into four value domain sectors. As a first step in the use of the CPPR 4.0 framework for addressing the issues of an Industry 4.0 environment (at the strategic and operational levels), we showed its practical application by developing a system dynamics model of the mass customization paradigm. The obtained results seem to suggest that the impact the Level of System Reconfiguration has on the Production Volume is bigger than the impact of the Level of Customization. The implications of these results for the sustainability issue come from the fact that creating a business model with a sustainable value proposition is possible when properly addressing the use of high levels of technology. Future research will address the use of the CPPR 4.0 framework and the development of a real-time, up-to-date, operational information reference model that, according to Reference [4], is required to support the two fundamental capabilities needed to effectively address the mass customization challenge [9], that is, to simplify the customization process; to assure the key resources/activities are suitable and scalable.

Author Contributions: In this paper, C.M.-O. and J.M.-V. were responsible for the design and writing of the whole paper. All authors have both read and approved the manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

According to Reference [1], the term “Industry 4.0” was first used in the 2011 Hannover Expo, where the leaders of the German Government emphasized the necessity of integrating all production processes and the close cooperation with information and communication technology (ICT) and machinery industries. As a response to this German initiative, other countries proposed their own initiatives [93]:

- The USA developed “A Strategy for American Innovation” for creating new jobs and strengthening ICT industry leadership and promoted an advanced manufacturing partnership for reviving the manufacturing industry based on the private sectors’ capability of Big Data, IoT, etc. In this case, the proposal is driven by several founding members from industry rather than the government.
- The European Union (EU) initiated a program called “Factories of the Future” for sustainable production while maintaining global competitiveness.
- Japan declared the “the 4th Industrial Revolution” as a national strategy, actively utilizing its strong robotics technology in order to increase industrial competitiveness and accelerate the socio-economic system.
- China is promoting the “Made in China 2025 Plan,” which represents an attempt to introduce IoT technologies within industrial value creation but with a different purpose: reaching the position of a leading industrial nation worldwide.
- The similar South Korea program aims to introduce digital technologies within industrial manufacturing is pursued under the title “Manufacturing Innovation 3.0,” 14 among many further programs worldwide.

For a more into detail comparison of these initiatives, the reader can refer to Reference [94].

Appendix B

- $LevCustom = RANDOM(0, 1)$; where a value of zero means low customization, and a value of one mean refers to high customization.
- $MinNumComp = 1$, $MaxNumComp = 6$; where a value of one refers to the case of products with low level of customization, and a value of six refers to products with high level of customization.
- $NumComp = (EXP(3 \times LevCustom)) \times ((MaxNumComp - MinNumComp) / 20.08553692)$
- $+MinNumComp$; the number of components (in a certain Product i), is dependent of the Level of Customization, and expressed in terms of an exponential function, to reflect the fact that this number does not increase linearly as the level of customization increases.
- $LevComp = IF(NumComp = MinNumComp) THEN (0) ELSE (NumComp / MaxNumComp)$; the number of components is normalized between the values of zero and one.
- $MinNumCompTyp = 1$, $MaxNumCompTyp = 3$; where a value of one refers to the case of products with low level of customization, and a value of three refers to products with high level of customization.
- $NumCompTyp = (EXP(3 \times LevCustom)) \times ((MaxNumCompTyp - MinNumCompTyp) / 20.08553692)$
- $+MinNumComp$; the number of components types (in a certain Product i), is dependent of the Level of Customization, and expressed in terms of an exponential function, to reflect the fact that this number does not increase linearly as the level of customization increases.
- $LevCompTyp = IF(NumCompTyp = MinNumCompTyp) THEN (0) ELSE (NumCompTyp / MaxNumCompTyp)$; the number of component types is normalized between the values of zero and one.
- $MinNumOWOQ = 1$, $MaxNumOWOQ = 6$; where a value of one refers to the case of products with low level of customization, and a value of six refers to products with high level of customization.
- $NumOWOQ = (EXP(3 \times LevCustom)) \times ((MaxNumOWOQ - MinNumOWOQ) / 20.08553692)$

- +MinNumOWOQ; the number of OWOQ (in a certain Product i), is dependent of the Level of Customization, and expressed in terms of an exponential function, to reflect the fact that this number does not increase linearly as the level of customization increases.
- $\text{LevOWOQ} = \text{IF}(\text{NumOWOQ} = \text{MinNumOWOQ}) \text{ THEN } (0) \text{ ELSE}$
- $(\text{NumOWOQ}/\text{MaxOWOQ})$; the number of OWOQ is normalized between the values of zero and one.
- $\text{MinNumProdVar} = 3$, $\text{MaxNumProdVar} = 6$; where a value of three refers to the case of products with low level of OWOQ, and a value of six refers to products with high level of OWOQ.
- $\text{NumProdVar} = (\text{EXP}(3 \times \text{LevOWOQ})) * ((\text{MaxNumProdVar} - \text{MinNumProdVar})/20.08553692)$
- +MinNumProdVar; the number of product variants is dependent of the Level of OWOQ, and expressed in terms of an exponential function, to reflect the fact that this number does not increase linearly as the level of OWOQ increases.
- $\text{LevProdVar} = \text{IF}(\text{NumProdVar} = \text{MinNumProdVar}) \text{ THEN } (0) \text{ ELSE}$
- $(\text{NumProdVar}/\text{MaxNumProdVar})$; the number of product variants is normalized between the values of zero and one.
- $\text{MinOperTime} = 1$, $\text{MaxOperTime} = 24$.
- $\text{OperTime} = (1 - \text{LevComp}) * \text{MinOperTime} + \text{LevComp} * \text{MaxOperTime}$; where the operation time increases linearly as the Level of Components increases.
- $\text{MinNumOper} = 1$, $\text{MaxNumOper} = 4$.
- $\text{NumOper} = (1 - \text{LevCompTyp}) * \text{MinNumOper} + \text{LevCompTyp} \times \text{MaxNumOper}$; where the operation time increases linearly as the Level of Components Types increases.
- $\text{LevTechnif} = \text{RANDOM}(0, 1)$, $\text{LevLabSkill} = \text{RANDOM}(0, 1)$; where a value of zero (in both cases) means low Level of Technification/Level of Labor Skills, and a value of one mean refers to a high Level of Technification/Level of Labor Skills.
- $\text{LevSysReconfig} = (\text{LevTechnif} + \text{LevLabSkill})/2$; the Level of System Reconfiguration is normalized between the values of zero and one (and assuming each element of the formulation has the same weight).
- $\text{TotOperTime} = \text{OperTime} \times (1 - \text{LevSysReconfig} \times \text{AdjFactor\#1})$; where the higher the Level of System Reconfiguration, the more the Operation Time can be reduced.
- $\text{AdjFactor \#1} = 0.9$; this factor is introduced to limit how much the Operation Time can be reduced.
- $\text{TotChangeOverTime} = \text{NumOper} \times (1 - \text{LevSysReconfig})$; where the higher the Level of System Reconfiguration, the more the Number of Operations (representing the changeover time) can be reduced even to zero.
- $\text{AvailableTime} = 100$; the total amount of production time available (arbitrarily established).
- $\text{ProductionVolume} = \text{AvailableTime} / ((\text{TotOperTime} + \text{TotChangeOverTime}) /$
- $(1 - \text{LevProdVar} \times \text{AdjFactor\#2}))$; in this case, the Level of Product Variety increases the Total Operation Time.

$\text{AdjFactor \#2} = 0.1$; this factor is introduced to limit how much the Total Operation Time can be increased.

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