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Resilience, agility and risk management in production ramp-up

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Abstract

Production ramp-up is challenged by several hurdles such as unpredicted events to achieve targets like providing on-time service in critical situations and under budget constraints. The interrelated concepts of resilience, agility and risk management increase the ability of the system to handle the changes effectively. Therefore, in order to successfully manage production ramp-up particularly in high variety environments, resilience, risk, and agility should be considered in a holistic way. This will help address complexity and uncertainty underlying manufacturing and service operations. This paper aims to fill this gap by reviewing the literature and reporting on the basic concepts and interrelationships of resilience, agility, and risk management in the ramp-up phase. Ultimately, the paper aims to lay some foundations for further research in the crossing of these areas.

Keywords: Ramp-up production; agility; resilience; risk management; production uncertainties.

1. Introduction

Nowadays, companies to win the market competition have to raise the variety of their offering to satisfy a larger panel of customers by presenting more individualized products [1]. Among the critical steps of the marketing of individualized products is the ramp-up phase, particularly in terms of when and how it should be conducted [2]. However, production ramp-up management is confronted with several challenges such as uncertainty on both demands and on capacity [3]. For instance, these uncertainties may lead to problems in product quality and therefore the associated cost should be taken into account in the definition of ramp-up budget. Agility and robustness play a major role in handling uncertainties on time in production systems [4]. An important consequence of agility is a quick response to environmental changes like customers' demands, supplier changes, pricing pressure, etc. In contrast, the aim of a robust process is the reduction or avoidance of any destructions. The concept of resilience is propounded to combine both agility and robustness to increase the ability of the system to handle the changes effectively [5, 6].

Resilience is closely related to and relying on risk management. Authors such as [7] explored bankruptcy situations in the construction industry of Belgian companies and revealed that the lack of effective handling of uncertainty by risk management was one of the major reasons of the bankruptcies. Risk management supports the identification of risk factors and their impacts during the ramp-up as well as suitable solutions [8].

In order to successfully manage production ramp-up particularly in high variety environments, resilience, risk, and agility should be considered in a holistic way. This will help address complexity and uncertainty underlying manufacturing and service operations. According to the authors' best

knowledge, no review paper is available to cover production ramp-up considering these three concepts altogether. This paper aims to fill this gap by reviewing the literature and reporting on the main basic concepts and interrelationships of resilience, agility, and risk management in the ramp-up phase.

The remainder of the paper is organised as follows, Section 2 describes the research methodology. Section 3 reports on the results of literature review. Section 4 discusses the identified papers out of the literature review. Finally, Section 5 provides conclusion and propositions for future work.

2. Research methodology

The aim is to conduct a systematic literature review to shed more light on resilience, risk and agility in ramp-up management. The approach proposed by [9] is identified as appropriate for the current research. They described that each systematic literature review has four steps: material collection, descriptive analysis, category selection and material evaluation. The literature search approach used to extract the relevant articles is iterative to refine the search parameters (e.g. key words, date of publication, etc.). The different steps of the procedure to extract the articles are presented as follows and the articles are summarized in table 1:

1. *Definition of the scope:* The databases and the journals are chosen such that they are representative of the research. The applied databases and search engines are *Science Direct*, *Scopus*, and *Google Scholar*.
2. *Paper selection:* The keywords used include the following *risk*, *agility*, *resilience*, *ramp-up*. The first filtering criterion of the papers is the time span; only papers published between 2004 and 2021 were selected. These include journal and conference papers. An initial search of the databases resulted in a total number of papers of 38 papers. 7 papers out of these are associated with risk analysis, risk management, challenges of risks in ramp-up production. 20 papers are concerned with the resilience concept (not only in ramp-up management due to the lack of studies). 13 papers of the studied articles are related to agility and its challenges in ramp-up management (see Figure 1). The papers cover fundamental studies or applications to industries such as automotive or electronics.

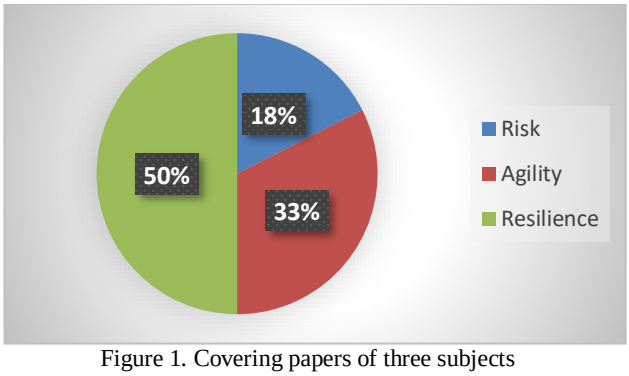

Figure 1. Covering papers of three subjects

Table 1. Summary of the identified papers

Reference	Risk	Agility	Resilience	Ramp-up
[1]				*
[2]				*
[3]		*		*
[4]		*		*
[5]		*		*
[6]		*		*
[7]	*		*	*
[8]	*			*
[9]				*
[10]	*			*
[11]	*			*
[12]	*			*
[13]	*			*
[14]		*		*
[15]		*		*
[16]		*		*
[17]		*		*
[18]		*		*
[19]		*		*
[20]			*	*
[21]			*	
[22]			*	
[23]			*	
[24]			*	
[25]			*	
[26]			*	
[27]			*	
[28]			*	
[29]			*	
[30]			*	
[31]			*	
[32]			*	
[33]			*	
[34]		*	*	
[35]			*	
[36]			*	
[37]		*	*	
[38]	*	*	*	

3. Results from literature review

1. Resilience

In today's complex manufacturing environment, failure and uncertainties become more frequent. On the one hand, including some approaches to handling these uncertainties is vital and on the other hand, having a resilient system is important. Resilience deals with unexpected challenges by presenting solutions to adversities. The resilience concept is identified by what, why, and how a system reacts when facing failures [10]. Hence, recognizing its characteristics was a challenge for researchers [11]. This concept has been applied in various areas; some researchers have included resilience as an attribute to deal with personal stress in enterprises [12] while [13-15] investigated through the topic of supply chain and controlling natural disasters. By exploring in the literature, it was seen that the resilience concept was addressed not only in

ramp-up but also in production systems at large. Therefore, the remainder of this section will focus on the large area of production systems.

Resilience of production systems relies on drivers such as closed loop of the tasks in production control, functional map of production control tasks, implementation of robust processes. An interesting point in [15] was the combination of two opposite concepts namely agility and robustness in resilience. The authors found that creating standard information in production ramp-up about the process of material flows has an effective role to set resilience system. Other authors studied the impact of several factors on system resilience [16, 17]. Among the growing orientations in production systems is the combination of resilience and lean production strategies. The impact of this combination on the maintenance and performance of the whole system was reported on in [18, 19].

Resilience is one of the drivers to achieve sustainability in the industry [20]. To assess this driver, [21] proposed a fuzzy model to reach the value of resilience factors. The authors determined that the suggested mathematical model could not give appropriate results while using a conceptual model could be more suitable. [22] studied the resilience of human machines during perturbations. Some series of possible learning scenarios were proposed to improve the resiliency of the system.

2. Risk Management

Customers' requirements are increasing day to day which lead to tough competition and frequent product development and ramp-up projects [1]. This results in larger number of product variants and recurring changes [3]. Therefore, manufacturers have to cope with products that are more complex in less time with less money and make sure to start production (SOP) on time.

Risk management is a key factor in the ramp-up of production to reduce uncertainties and disruption in the manufacturing systems. Early identification and minimization of the risks of ramp-up can lead to effective actions and suitable response strategies during the transition step [23]. In production systems such as in the automotive sector, if a price for each product is considered 25.000€ and 25000 cars are produced per month, 44€ million will be lost if the manufacture is undertaken a risk of SOP reduction to obtain a return on the sale of 7% besides reduction of the product life cycle in one month [24].

There are different approaches to risk management that depend on the applied sector; for example in car manufacturing top-down risk analysis is commonly used to model the risks [24]. Risk management approaches (top-down) in ramp-up projects of car manufacturing can be categorized into four models [24], 1) Planning and organizational models, 2) coordination models, 3) knowledge management models, and 4) central defects and need for action were considered in the paper. In automotive sector, surveys can be used to determine and model risks in the sub-process of pre-series logistics [25]. In hybrid manufacturing technologies, ramp-up production is more challengeable than single products. [26] proposed a systematic design approach to hybrid manufacturing and software a method was suggested to evaluate the risks in the ramp-up production.

3. Agility

Unpredicted events in the ramp-up phase prevent the system from obtaining targets on time. Agility is likely to help companies deal with unpredicted events and reach time-to-volume without exceeding the ramp-up budgets [27]. Furthermore, agility can provide the right product at the right time [28]. [29] studied agility application in the metallurgy industry. It was shown that early and reliable information on product and process maturity has an important impact on ramp-up production.

The papers report on several approaches to improve the agility in production ramp-up. Analysis of the manufacturing context and proposing data system implementation is one of the approaches applied in electronics manufacturing systems studied by [30]. [31] proposed creating a relation among critical parts of supply networks and operational activities for production ramp-up through a conceptual experimental framework. They argued that systematic ramp-up production is very important to achieve time-to-volume. In the ramp-up phase of physical products for the agile product development, [32] proposed an adaptive engineering change management (ECM). This approach is guided by the following initial questions: What is the data structure? How processes are implemented and what are the roles? Finally, what are the communication tools? Based on these challenges a three-layer model with a responsive design was proposed [32]. Collecting real-time data via approaches of industry 4.0 can support the learning and decision-making process to improve the agility in ramp-up production [33]. [27] mentioned two challenges in agile production ramp-up; the first one is the identification of adjustment levers to manage the uncertainties in production ramp-up and the second one is to develop a concept to stop a predetermined design in the contract.

4. Discussion

The previous sections shows some commonalities as well as complementarities between the various concepts. For example, what can be observed in the literature of agility is the focus on timely response to change and change management to survive and dealing with diversities [34] to satisfy the market needs. Indeed, in agility, the speed of responding to the changes is more important than resilience [35, 36]. [37] clarified different and common features in agility and resilience concepts in the supply chain that interested readers can refer to. In Figure 2 the common and distinctive features of the two concepts are illustrated.

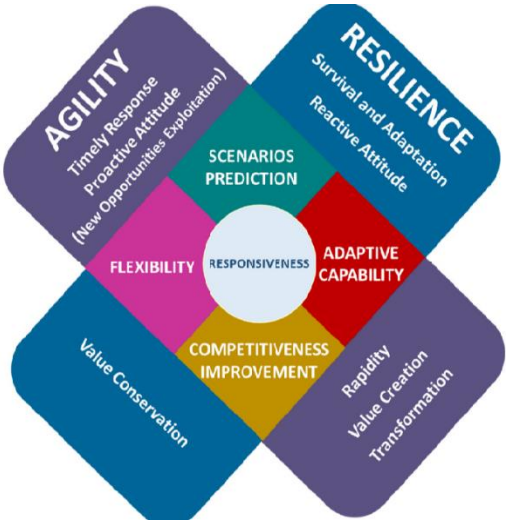

Figure 2. Common and distinctive features of agility and resilience [36]

Manufacturing and service operations are becoming exponentially more complex. This adds to the challenges ahead of academics and practitioners in the broad field of industrial management. More specifically, ensuring the resilience of the system, be it a production system or a supply network, is confronted with more difficulties such as the uncertainty induced by changing enterprise operating environment and evolving customer requirements. Therefore, a holistic approach integrating resilience, agility, and risk criteria is required for manufacturing and service companies. The ramp-up phase as a driver of product introduction in the market should integrate these criteria.

To this end, the interrelationships between resilience, agility, and risk should be explicitly defined to unleash their synergies. From a more practical point of view, these criteria should be taken into account at various levels during ramp-up, organizational, information system, and operational levels. This perspective could benefit from existing works such as [26, 38].

The literature review presented in this paper, uncovered also some thematic areas, which might need further investigation; this includes learning and human factors, risk, and sustainability. The learning process has a prominent impact on production ramp-up particularly from an agility point of view. The learning process affects heavily the adaptation of personnel when unpredictable events occur during ramp-up. Moreover, in the ramp-up phase, to handle risks one should have a comprehensive view of various risk factors to provide appropriate mitigation plans limiting temporal and financial changes. Furthermore, sustainability in ramp-up production has not been investigated extensively in the literature. Hence, there is a research potential in the literature. Among the questions to be addressed at this point, can be cited the following, how sustainability can be still improved during ramp-up? How sustainability assessment can be integrated within the triptych resilience, agility, and risk? [38].

Finally, most of the addressed case studies are in electronics or automotive sectors. The critical situation due to COVID-19 showed that agility, risk, and resilience in ramp-up production should be included in new industries (ex. ventilators). It is an important lack in the literature that can be addressed in future research work.

5. Conclusion

This paper presented and discussed a literature review of resilience, agility, and risk in production ramp-up. The vast majority of the reviewed studies support that all three concepts are a key for ensuring enterprise competitiveness, particularly under critical conditions. However, the further investigation involves addressing the interrelationships of these concepts to unleash their synergies and to adapt to changing environments.

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