REVISITING THE CONCEPT OF FLEXIBILITY

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ABSTRACT

Research studies indicate the existence of three generic ways for dealing with variation: control, flexibility and buffering. These are the ways of assuring organizational robustness to support the proactive and reactive management of events that occur during the project life cycle. Traditionally, project management practices have strongly relied on the combined use of control and buffers. However, the growing recognition of problems associated with organizational complexity has been changing paradigms and pushing structural changes towards the development of flexible competences.

This paper critically discusses the concept of flexibility, regarding its definitions applied to construction projects. The first objective is to provide a better understanding of the concept by looking at its inter-relationship with control and buffering. The three concepts are explained as different but complementary ways of handling variations. The second objective is to show that, in any context, the emergence of a flexible competence is the result of many internal adjustments in the content of production strategy. The idea is to present flexibility as a multi dimensional concept that requires a core discipline and various enablers. In doing so, the authors hope to provide further understanding of the inner workings of production system robustness and to highlight the important role of lean practices.

KEYWORDS

Flexibility, buffering, organizational robustness, production system design.

INTRODUCTION

There has been an increasing awareness that the project management approach is insufficient to ensure workflow stability in large-scale product developments. Experimentation with lean control initiatives shows that improving the timely availability of materials, information, and resources is not enough to generate a significant better project performance. Consequently, some practitioners and academics have been breaking away from the limited project management approach and paying attention to strategic choices in production strategy that require a more organizational level perspective.

The main driver for the change has been the acknowledgement of problems associated with organizational complexity. This has been leading firms to break

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paradigms and to recognize that systemic stability can be improved through the utilization of all available resources. As a result, more than just trying to adequately place and size resources, the firms are looking to develop new roles for project managers, decentralize functions and exploit the competence and creativity of all stakeholders, especially the workforce. But to do so, they must critically analyse the strategic choices and bundles of practices that shape the production systems and, consequently, affect the emergence of flexible production competences.

In accordance with these aspects, the following topics discuss theoretical issues that form an important background for the development of system flexibility types. Investigation into this subject is particularly promising because it is fundamental to the issue of systemic stability and thereby to the development of a more comprehensive theory for project production. The flexible production competences and capabilities arising inside production systems are intrinsically linked to the goals of value generation and waste reduction (e.g., Ballard et al 2001), since they address both production situations and uncertainty regarding customer requirements. Therefore, if a theoretical foundation is needed to describe the emerging project production model, the fundamentals and enablers that generate flexibility types within organizations are worth investigation. Research on flexibility may be able to provide a comprehensive picture of why and when lean construction practices work best.

REVISITING THE CONCEPT

FLEXIBILITY AS A WEAPON ON THE MANAGER'S ARSENAL

Management can be both proactive and reactive at the same time. According to Monostori et al. (1998), proactive management is a behaviour aimed at fostering anticipation, learning and coherence. It is generally a process of preventing anticipated disturbances as early as they are foreseeable from monitored and sampled performance trends. On the other hand, the authors describe reactive management as a behaviour aimed at achieving an adaptive coordinated response to changes. It is an event-driven incremental repair process to current internal and external circumstances. Both proactive and reactive management decisions should be based on real time monitoring and a continual data-acquisition in the shop floor.

Despite the common belief that good management is primordially proactive instead of reactive, both proactivity and reactivity must be combined for the effective fulfilment of performance goals (e.g., Monostori et al. 1998). In other words, reactive management does not necessarily mean lack of planning. As Schmenner and Tatikonda (2005) put it, the study of the Japanese flexible factory has not only led researchers to question whether tradeoffs (e.g. cost versus quality) actually exist, but has also shown the important complementarity between proactive and reactive management. Therefore, reactive management can have a positive impact if flexibility types are used to move the production system quickly, smoothly and cheaply from one state to another.

FLEXIBILITY AS THE CENTRAL ELEMENT OF ROBUST PRODUCTION SYSTEMS

Robustness is commonly mistaken for redundancies in task-resource allocation. However, from a strategic perspective, control, flexibility and buffering are complementary ways of dealing with the same problem: variation. Together they comprise the set of strategies, capabilities and capacities that build organizational robustness and, therefore, must be rationally used to support proactive and reactive management during the project life cycle. Despite the major developments in industrial management, most research studies have only examined superficially the mechanisms behind their inter-relationships, especially when used in different organizational structures. Nevertheless, a comparative analysis indicates the importance of carefully applying them according to the conditions because each handles variation in a different manner:

- Control (action): practices and strategies that identify and influence the occurrence of events with the objective of preventively reducing their effects on the system;
- Flexibility (reaction): capabilities that quickly adapt the system in response to the effects of changes, without inflicting damage to production goals;
- Buffering (conformation): redundancies that allow the system's structural arrangement to accommodate disturbances and variation.

In manufacturing, Corrêa and Slack (1994) found evidence of a hierarchic application in which control mechanisms are used as "filters" that restrict the amount of changes to be dealt by the production system. Standardizing, focusing, advertising/promoting, and monitoring are amongst the event control-related managerial actions (e.g., Corrêa and Gianesi 1994). Some changes and their effects that pass through the "filters" are managed by flexibility types within the system. However, Slack (1987) mentions that the control schemes are incapable of dealing with all variables and that flexibility is preferably avoided by companies due to its high development costs. Consequently, buffers are used to handle the rest of the variations due to their broader applicability. In summary, the three constituents of organizational robustness comprise the layers of strategies, capabilities and capacities that support systemic stability by reducing the number of events that cause dynamics and the non-linearities within the dynamics.

Regarding the construction sector, it is well-known that the development of tools and practices for production planning and control is the most studied topic (e.g., Ballard and Howell 1997, Alarcón et al. 2005). Additionally, buffers are widely used to help achieve systemic stability. In fact, several studies (e.g., Sakamoto et. al., 2002; e.g., Nielsen and Thomassen, 2004) have shown the proper sizing and location of buffers to positively impact on project performance. But there has also been a growing interest in the implementation of different types of flexibility within project production systems (e.g., Martucci and Fabricio 1998, Ebert and Roman 2006).

While studying the requirements for creating a system flexibility type at the level of operations, Miranda Filho (2008) found that multi-skilled work teams supported by enablers of vertical and lateral relations possess reliable and timely information for control purposes and therefore do not need self-contained tasks and slack resources within their work packages. This allowed project managers to remove redundancies from those individual trades without risking underperformance. The time removed from the work teams was used to form the project buffer. Complementarily, because of the high workload and optimal design of the teams, feeding buffers needed to be deployed in front of their work packages in the critical chain. Thus, the study confirmed that a system flexibility type requires the support of control mechanisms in order to be effective. Furthermore, the study strongly indicated that flexible competences within the production system should guide buffer management.

The discussion above suggests that an adequate analysis of robustness in both manufacturing and construction must encompass the three ways of handling variations, as they are crucial elements to both proactive and reactive management. Furthermore, flexibility appears to be the strategic element of organizational robustness that guides the development of control and buffers types (Figure 1).

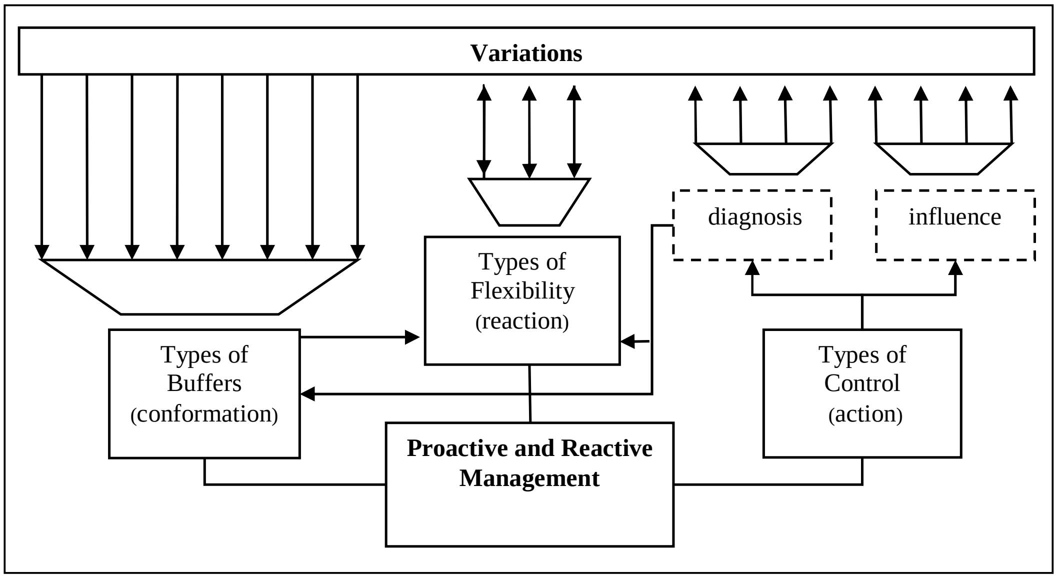

Figure 1: Variation Management as a Balance between Action, Reaction and Conformation.

FLEXIBILITY AS THE ABILITY TO ADAPT INSIDE A SET OF PREDETERMINED STATES

The need to distinguish simple buffering from flexibility is primordial to understanding the strategic nature of the latter. While firms may not be able to prevent all problem-causing variations, they can learn to recover from some of them with little, if any, harm to performance. Therefore, flexibility is commonly defined as the ability to respond effectively and efficiently to changing circumstances (e.g., Schmenner and Tatikonda 2005). It is a strategically important attribute for a firm competing in a marketplace with given variation types. For this reason, Sánchez and Pérez (2005) mention that a comprehensive view of the production function calls for distinguishing flexibility in three ways: (1) basic flexibility types or flexibility of individual resources (flexible competences); (2) system flexibility types or composites of the basic flexibility types at the production system level (flexible competences); and (3) aggregate flexibility types or flexibility of the production system as a whole (flexible capabilities).

According to Zhang et al. (2006), a flexible production competence, which includes machine, labor, material handling, and routing flexibilities, is a key internal dimension of competition that is invisible to costumers. Differently, a flexible production capability, such as product, volume, delivery and mix flexibilities, is an external dimension of competition that is perceived and valued by costumers. Therefore, it has an impact on the relationships with customers. Both dimensions are interrelated because flexible competences support the system's flexible capabilities.

As for buffering practices, in this paper buffers are understood as resource cushions, i.e., money, time, materials, space, etc., used to protect processes against variation and resource starvation (e.g., Alves and Tommelein 2004). Alves et al. (2006) mention the importance of acknowledging the effect of variation in the definition of buffer profiles, which can be described in terms of type, place and size. In highly uncertain and variable conditions, like project production in the architecture, engineering and construction industry, buffers have a role to play in absorbing unexpected changes in customer orders, problems with defective products, variations in production with long lead times, and problems with material shortages. Buffers help to keep certain dynamics from pushing to the limit the closest currently active constraints in the subsystems. Hence, buffers can exist at the worker, team and project levels and can take many forms including: inventory (materials), work-in-process (subassemblies), time (deliberate and unintentional delays), and excess capacity (labor and equipment).

The distinction between flexible competences and buffering is a prerequisite to understanding how they impact on aggregate flexibility (flexible capabilities). First of all, both types of initiatives may originate from deliberate strategies. However, basic and system flexibility types do not come without a cost because structural changes are required to create the competences necessary to respond efficiently to variations. Differently, buffering may appear to be an easier solution, but it does not contribute to the overall efficiency. Hence, although both concepts can support customer satisfaction, only flexible competences allow it to be achieved efficiently.

The failure to distinguish the concepts can often lead to misunderstandings. For instance, Corrêa and Gianesi (1994) have mentioned that the more flexible the production system the more difficult it is to maintain consistency in terms of cycle time and quality. This affirmation does not specify that, in such cases, aggregate flexibility is being more supported by redundancies than by flexible competences. In other words, it makes no clarification or simply ignores the fact that excessive buffering may be the cause of poor performance.

Because of the above reasons, it is a conceptual misunderstanding to describe flexibility as a response to unexpected changes. On the contrary, flexibility is the adaptation of a particular system inside a set of predetermined states. Therefore, this paper proposes that systemic efficiency depends on limiting the number and degree of variations the subsystems endure and on making the structural arrangements that originate the flexible competences to match the changes. Exposing the subsystems to a wider set of states than what was originally intended implies allocating to them buffer types to absorb different variation types. This, in turn, jeopardizes the performance goals just as much as not placing the buffers would too. Consequently, flexibility types need to be complemented with control mechanisms in order to keep subsystems within a deliberate set of states. The most imperative thing that should be kept in mind is that a firm is flexible in adapting to variation part because it is proactive in controlling it.

More research along this line is required because it can bring clarifications to the goals of waste reduction and value generation in project production. The flexible production competences and capabilities within production systems are intrinsically linked to the achievement of such goals, since they address both production situations and variations in customer requirements (Figure 2). Flexibility combined with control is what makes it possible to be effective while being efficient.

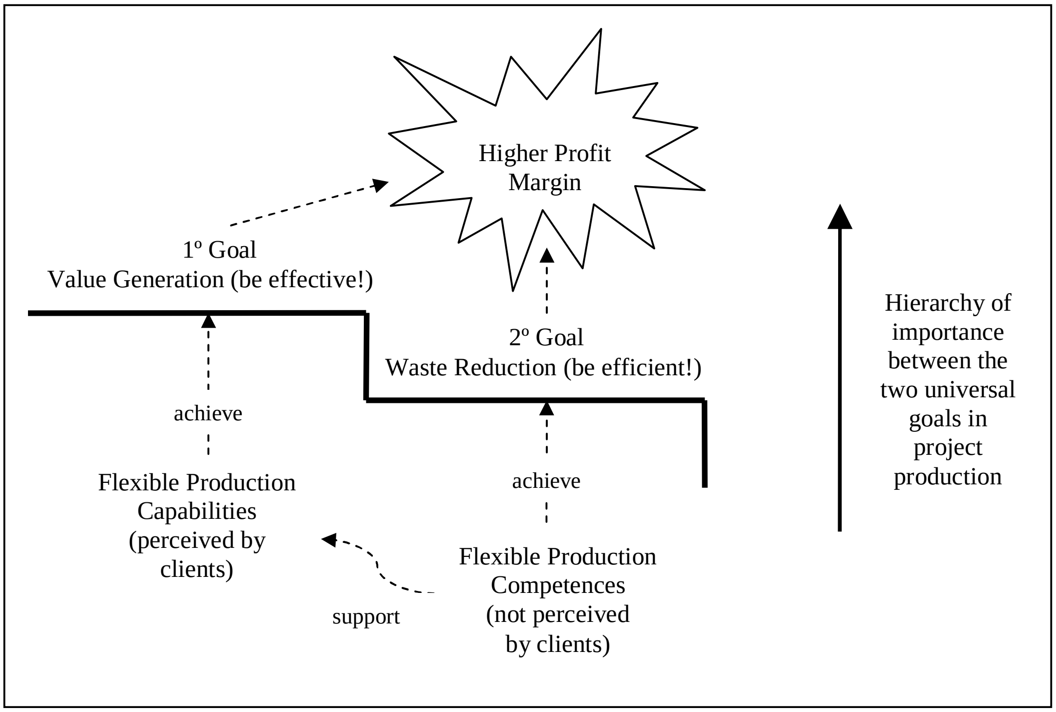

Figure 2: Effectiveness and Efficiency Resulting from the Enhanced Flexibility in Project Production.

FLEXIBILITY AS THE RESULT OF SYSTEMIC INTEGRALITY

In manufacturing, Slack (1987) observed that most managers focused more on flexibility as it applied to the individual resources of manufacture as opposed to the flexibility of the production system as a whole. Oppositely, in the construction industry the focus has been on aggregate rather than on basic or system flexibility types. Among the causes are centralized decision-making, poor organizational integration and changes in customer orders. Consequently, aggregate flexibility types (flexible capabilities) have been mostly achieved through buffering. Therefore, the development of system flexibility types (flexible competences) that contribute to efficiency and effectiveness within project production systems remains lacking a comprehensive perspective.

Nevertheless, research and experiments conducted on manufacturing firms have provided insights into the factors behind the emergence of system flexibility types. As mentioned before, a flexible production competence does not come without a cost. It is important to acknowledge the combined enablers – procedures, policies, resources, design decisions and other factors that make possible the development of flexible production competences and other internal sources of competitive advantage. According to Slack (1987), flexible technology cannot be totally effective without flexible labour and vice versa. Neither can be effective without a set of procedures, systems and controls which are themselves capable of coping with the flexibility of the physical processes.

The critical role of enablers can be exemplified by cell production, which is often categorized as a system flexibility type. Cell production is an application of group technology. Hyer and Brown (1999) describe group technology as an alternative method of organization to work structuring based on process specialization. As discussed by Burbidge (1996), the essential step in group technology is to plan a total division into groups and families, in which each group completes all the parts it makes. Evidently, the flexibility of the equipment and bandwidth of worker skills determine the range and sets of parts that can be made by the same group. The author adds that this step is followed by changes needed to install the groups and get them running, such as plant layout, changes in operating and payment systems, manning of groups, and training. This example highlights the substantial number of arrangements needed to create system design features that support the emergence of a system flexibility type.

Moreover, research studies have found that, despite differences in the content of strategies and design, production systems share a common aspect when it comes to flexible competences. This aspect, however, can only be perceived if the understanding of flexibility development is extended beyond issues of structural and infrastructural decisions.

Under the new production paradigm, the production systems are being founded on an integrative discipline that has yet to be fully understood. Many forms of proximity have long been considered primordial for production systems to develop different kinds of flexibility against different kinds of variations (e.g., Buiar 2000, Schmenner and Tatikonda 2005). Hence, the existence of enablers promoting proximity between participants, tools and tasks is the common aspect behind the emergence of flexible competences within production systems.

Because proximity can take many forms, it is, therefore, the result of strategic, tactical and operational level decisions. In this paper, proximity in multiple dimensions is called integrality.

Research on cell production has also provided evidence of integrality supporting the emergence of a system flexibility type. According to Hyer and Brown (1999), the real manufacturing cells are characterized by more than just the dedication of resources to a family of parts which have similar processing requirements. The authors mentioned the proximity between the workers in terms of know-how and work standards. Furthermore, the authors observed that the discipline of cell production also involves the creation of a work flow where required tasks and those who perform them are closely connected in terms of time, space and information. Although it is not clearly stated, the authors recognize the production cells as integral subsystems requiring proximity between the participating entities. They believe the time, space and information linkages among people and tasks to be the common denominators that distinguish cells from other manufacturing constructs.

The positive impacts of integrality have been gradually gaining recognition inside the construction industry. Although formal integration between value chain activities is out of question in a highly fragmented industry, interaction and trust issues in cooperative networks have increased the awareness of the need for strategies promoting, as much as possible, the proximity between project participants in terms of culture, organization, technology, and geography. Greater proximity in these dimensions is perceived to improve the quality of relationships among participants during project execution. As argued by Santos et al. (2002), pull production, anticipation of problems and workflow stability are improved when team members work closer to one another and complete a larger set of closely affiliated subsequent and adjacent tasks.

The creation of such working conditions is advocated by lean construction practitioners and academics as crucial to increasing the probability of project success. This indicates that lean construction is well aligned with the notion of integrality. As a matter of fact, some lean practices enhance the interconnections between site personnel and tasks (e.g., Visual Management, 5S, etc.), improving response flexibility. At the same time, other lean practices seek influence over upstream factors (e.g., Last Planner System, Kanban, etc.), reducing the amount of variations the work teams have to endure. Thus, production strategies, policies and practices founded on lean principles can become enablers of flexibility types within project production systems. In other words, construction firms taking the path towards lean construction are also taking steps towards the development of flexible production competences.

CONCLUSIONS

In construction projects, the development of system flexibility types becomes increasingly important as the focus shifts from management-as-planning to management-as-organizing. Under the new paradigm, the development of system flexibility types is seen as a way to reduce tradeoffs between competitive criteria and thereby achieve project goals. However, the requirements for creating a system flexibility type at the level of operations and how it affects control and buffer types in the project production system still lack a comprehensive understanding. Moreover, due to the newness of the subject, research that combines strategic choices in production strategy with theoretical frameworks to understand the achievement of particular flexibility types is still an emerging area in project production.

In order to understand the production system design features that support flexible production competences, this paper distinguishes the concept of flexibility from the concepts of control and buffering. It is proposed that the three concepts should be seen as the pillars of organizational robustness, with flexibility being the central pillar around which control and buffers are developed. This study argues that system flexibility types supported by control types reduce the need for self-contained tasks and slack resources within work packages. Consequently, flexible competences within the production system should guide buffer management. These ideas highlight the importance of paying more attention to infrastructural decisions when developing project production systems because of their top-down effect over structural decisions regarding the definition of resource capacity and allocation of buffers.

In fact, the exploratory literature review clarified that true system flexibility types arise from adjustments between strategic choices, organizational policies, production practices and management style. It showed that any system flexibility type is by itself a multidimensional concept, requiring various enablers to be effective.

The research also indicates integrality as the core discipline behind the emergence of flexible production competences. Proximity in multiple dimensions has long been considered primordial for production systems to develop different kinds of flexibility.

Furthermore, the finding that lean construction is well aligned with the notion of integrality helps to explain the positive impacts and minor tradeoffs caused by lean practices in civil construction. As observed, such practices enhance the interconnections between site personnel and tasks, while at the same time permitting influence over upstream factors. This shows that lean practices can become enablers of flexible production competences and therefore need to be carefully combined with strategic choices that support proximity in other dimensions.

Further research is needed to confirm and expand this understanding of flexibility development. Future studies in lean construction could address the subjects of integrality and flexibility, because both are fundamental to the issue of systemic stability.

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