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SLACK IN CONSTRUCTION - PART 1: CORE CONCEPTS

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ABSTRACT

Construction projects are known to be complex, due to being subject to uncertainty and variability. The use of buffers to protect them from the detrimental impact of variability has been well-researched. A key managerial choice is not whether or not to buffer variability, but rather how to define the necessary combination of buffers. Slack is a concept related to buffers but has been used in the literature to describe a broader range of strategies for coping with complexity. It allows an organisation to adapt to internal pressures for adjustment or to external pressures for change in policy. This paper aims to further develop the concept of slack and to unveil its relationships with other concepts and ideas that are partly overlapping such as buffers, resilience, robustness, flexibility, and redundancy. A concept map was devised in order to articulate the nature of the slack concept. This paper explores in detail this concept map and proposes a conceptual role for slack in the realm of Lean.

KEYWORDS

Slack, buffer, complexity, variability, uncertainty, concept map, waste.

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INTRODUCTION

Construction projects are known to be subject to uncertainty and variability. The use of buffers to protect them from the detrimental impact of variability has been well-researched and goes back to developments of inventory management theories (Spearman and Hopp, 2020). In past IGLC conferences several papers explored the benefits and drawbacks of buffers in construction projects (e.g., Horman et al., 2003; González et al., 2008) and were grouped under a track named Buffer Management.

Alves and Tommelein (2003) defined buffer as a cushion of resources used to protect processes against variation and delays in the delivery of resources. The suitability of certain types of buffers over others may vary according to the existing environment (Buchmann-Slorup, 2014). In construction projects, materials, time, and money are the types of buffer resources mostly accounted for, especially in production planning and control. Therefore, a key managerial choice is not whether or not to buffer variability, but rather how to define the necessary combination of buffers.

The emphasis on time and financial buffers makes sense as they are versatile resources that can address a wide range of risks. Furthermore, money can pay for capacity buffers, which is another strategy to cope with variability in construction projects (Tommelein, 2020). However, time and money can make a difference only if associated with other types of resources such as equipment, materials, labour, and space, e.g., overtime work is only useful if reliable equipment and workers are available; and money is pointless if required supplies are not available for sale.

Slack is a concept related to buffer but has been used in the literature to describe a broader range of strategies for coping with complexity. Bourgeois (1981) defines slack as a cushion of actual or potential resources that allows an organisation to adapt successfully to internal pressures for adjustment or to external pressures for change in policy. Lawson (2001) pointed out that slack plays a key role in organisational work so that people can pay attention, think, and benefit from knowledge – this is particularly important in complex projects, which require more, not less, time for monitoring and processing information. Saurin and Werle (2017) argued that slack can be created by using different strategies and a wide range of resources (e.g., time, information, material, people, money, and equipment).

The slack concept has been used in disciplines such as organisational behaviour (Lawson, 2001), innovation management (Huang and Chen, 2010), and complexity theory (Saurin and Werle, 2017). In Lean Construction, slack has also been approached by a few earlier studies. Bertelsen and Koskela (2005) defend the provision of slack for the management of complex projects. Fireman and Saurin (2020) discuss the role of slack for the reduction of waste, as it prevents failures in making-ready from immediately becoming making-do waste. Saurin (2017) argues that slack may be interpreted as a dimension of project risk management, since it involves a ubiquitous trade-off in construction projects, namely the extent to which processes should be shielded against variability without compromising efficiency.

In this research work, construction projects are regarded as complex socio-technical systems (CSSs) and must be managed as such. This implies the need for supporting resilient performance, which is the expression of how systems cope with both expected and unexpected conditions by adjusting their performance while maintaining the production of required outputs (Hollnagel, 2017). Although the use of buffers is a key strategy for creating resilience (Saurin and Werle, 2017), their use has been explored from a limited perspective. In fact, Ballard et al. (2020) argue that buffer management techniques are conceived to deal with variability that is statistically described in advance. However, when uncertainty is hard to anticipate and quantified, the narrow concept of buffer has little value (Ballard et al., 2020). Furthermore, the concept of buffer is focused on built-in and designed strategies and resources, thus neglecting resilient performance that arises from self-organisation, initiative-taking, and resourcefulness of employees. Furthermore, Iqbal et al. (2015) suggest that the focus on preventive risk management techniques does not guarantee that risks are eliminated before execution of a project and, therefore, that remedial risk management techniques, such as close coordination with subordinates and subcontractors, need to be used to reduce any risk impact.

Moreover, the need for being prepared to cope with a wide range of risks has been dramatically visible since the rise of the COVID-19 pandemic, which has affected the construction industry in many countries. Although the pandemic is a black swan (Taleb 2007) event, it stems from the same source as more mundane risks, namely the external environment that is a permanent source of uncertainty. These limitations of the buffer concept in combination with the assumption that construction projects are CSSs, demands a new terminology and theorisation capable of: (i) integrating a wide range of risk coping mechanisms that account for both formal and informal approaches, across all relevant processes at the micro, meso, and macro levels; and (ii) inspiring a revision of Lean Construction practices so as to check (and increase) the extent to which they are fit to address the growing levels of complexity and risk that characterize construction projects.

This paper aims to develop the concept of slack and to unveil its relationships with other concepts and ideas that are partly overlapping such as buffers, resilience, robustness, flexibility, and redundancy. This analysis is intended to assess the novelty and utility of the slack concept from the perspective of the Lean Construction community.

This study is not the outcome of a conventional research project, but it is the result of theoretical discussions carried out by a group of 13 academics – 5 professors and 8 graduate students - from three universities located in different countries (Brazil, UK, and USA) was formed and held 10 weekly on-line meetings during a 4-month period. The motivation for setting up this group was the perceived potential of the slack concept as an innovation in Lean Construction, based on earlier IGLC publications and research being conducted on that topic in the universities involved. The group meetings were focused on the discussion of papers on slack to establish a shared vocabulary and increase awareness of the state-of-the-art in construction and other sectors. Then, a concept map was collaboratively devised to articulate the nature of slack. This map sets a basis for a companion paper (Saurin et al., 2021) with examples and suggestions for further research.

WHAT IS SLACK?

Slack has been defined as a means to absorb uncertainty by using different types of resources (Saurin, 2017). Slack can be implemented by adopting measures that are planned in advance or that are defined in an opportunistic way. Saurin and Werle (2017) pointed out that slack does not necessarily imply extra or idle resources, as the existing resources can be adapted to a different use in order to cope with variability

Bourgeois (1981) discussed the perspective of organisational slack, suggesting three main roles for slack: (i) spare resources to prevent ruptures in the face of a surge of activity; (ii) resources that enable an organisation to adjust to shifts in external environments; and (iii) resources that allow an organisation to experiment with new products or innovations in management. Moreover, Bourgeois (1981) also identified four reasons for having slack: (i) inducement for attracting organisational participants and to maintain their membership; (ii) conflict resolution, mostly due to goal incongruence of local rationality; (iii) buffer in the workflow process (named technical buffer); and (iv) facilitator of strategic behaviour, which includes improvement and innovation initiatives. Therefore, besides coping with uncertainty or emerging events, slack can be used to fulfil demands or perform actions at a higher strategic level than is the case for buffers.

By contrast, the narrow definition of buffer as a cushion to protect processes against variability is frequently adopted in the literature. Previous studies have pointed out that the management of buffers is crucial for helping to achieve a desired level of outcome, and this is usually done by modelling the known, existing variability (Alves and Tommelein 2003; González et al. 2008). This definition of buffer is similar to the concept of technical buffer, proposed by Bourgeois (1981), which is not concerned with high-level organisational issues, such as innovation, conflicts, and strategic issues.

Another concept related to slack, used in the project management literature, is safeguard, defined by Gil (2007) as "the design and physical development work for ensuring, or enhancing, the embedment of an option in the project outcome". This definition seems to be mostly focused on work-in progress, and also on financial slack.

HOW TO IMPLEMENT SLACK?

Fireman et al. (2018) state that the implementation of slack depends on the definition of both slack resources (“what” question) and slack strategies (“know how” question). As mentioned, many different types of resources can function as slack, such as inventories, time, equipment, people, money, and information. There are different ways of categorising slack resources: (i) actual or potential: actual means that resources are somehow more than the minimum necessary to produce a given level of organisational output, while potential is related to providing people the ability to learn to be able to respond (Lawson, 2001); (ii) opportunistic or planned: planned means that the slack resources have been devised previously, considering the characteristics of the production system. By contrast, opportunistic slack exists when a resource can be used as slack despite not being its original purpose (Righi and Saurin, 2015); (iii) Time to release: some resources can be released immediately, while others may take some time to be used (Lawson, 2001); (iv) Time available: it is concerned with the time when the slack resource is available. (v) Degree of visibility: slack resources may have different degrees of visibility for the people that might demand them (Righi and Saurin, 2015).

Slack strategies can be classified in two core categories, redundancy, and flexibility. Redundancy implies excess, i.e., additional resources that are made available. Different forms of redundancy can be used, including backing up through duplication and redundant procedures (Saurin and Werle, 2017) or functions (Roberts, 1990). Hoepfer et al. (2009) suggested two categories of redundancies: (i) standby, when resources are neither loaded nor operational; and (ii) active, when the individual performing a redundant function is involved in the task at hand, and therefore is fully operational.

Flexibility is related to the fact that several resources can be used in different ways, e.g., multi-skilled workers, multi-purpose equipment. In the case of human resources, the concept of adaptability has been used to explain the capacity of human actors to change by self-organising, usually with the aim of being resilient in response to internal or external stimuli (Walker et al. 2004). Pulakos et al. (2000) stated that this is a function of the social portion of the system, being concerned with how easily workers adjust and deal with the unpredictable nature of situations, how efficiently and smoothly they can change their orientation or focus when needed, and to what extent they take reasonable actions.

Saurin and Werle (2017) proposed another category of strategy, named margin of manoeuvre, which is concerned with the degree of freedom to act, i.e., resources or people can be reordered according to the necessary conditions. Stephens et al. (2011) sub-divided margin of manoeuvre into three types: (i) maintaining local margin by restricting other units' actions or borrowing other units' margin; (ii) autonomy to create margin via local reorganisation or expand a unit's ability to regulate its margin; and (iii) coordinated, collective action of recognizing or creating a common-pool resource on which two or more units can draw. However, it seems that margin of manoeuvre represents a combination of redundancy, in some cases borrowing from other units, and flexibility, based on the autonomy of individuals or groups of people.

Saurin and Werle (2017) recognized work-in-progress as a category of slack strategy, although it can also be considered as a particular case of redundancy. It is a type of slack widely used in construction projects. From one perspective, it is regarded as an inventory of unfinished products, or alternatively as a backlog of available workplaces, which are often used as a mechanism to cope with the lack of reliability of flows (Viana, 2015).

WHY IS SLACK NEEDED?

There are two major reasons for using slack. One reason, from the organisational perspective, is to have resources for fulfilling demands or carrying out actions at a strategic level (e.g., innovation, establishing coalitions), as suggested by Bourgeois (1981). The other reason, from the production system perspective, is related to the fact that many projects must be considered as CSSs, particularly in the construction industry.

Project complexity can be described by two dimensions: structural complexity and uncertainty (Williams, 1999). Structural complexity arises in systems with many varied interrelated parts and can be interpreted in terms of differentiation and interdependency (Baccarini, 1996). Thus, the degree of complexity is associated with the number of parts as well as the extent of their interrelationships (Klir, 1985). This definition can be applied to different project characteristics, such as organisation, technology, environment, information, decision making, and systems (Baccarini, 1996).

Structural complexity is strongly related to the degree of coupling between two units, (Dubois and Gadde, 2002). Tight coupling pertains not only to the number of connections or shared variables between two units, but also to the brittleness that those connections bring to the system (Roberts, 1990). Loose coupling exists when units may be responsive to each other yet show independence in terms of effects on other units.

Uncertainty, the second dimension of project complexity, can be related to project goals (how well defined the goals are), and means (how well-defined the methods of achieving those goals are) (Williams, 1999). In either cases uncertainty might be affected by internal or external factors. In some situations, uncertainty is likened to variability, which has been defined by Hopp and Spearman (2011) as the quality of non-uniformity of a class of entities, being divided into process variability (created by things as simple as work procedure variations and by more complex effects such as setups, random outages, and quality problems) and flow variability (created by the way work is released to the system or moved between locations).

As mentioned, variability is often considered to be a predictable form of uncertainty. By contrast, uncertainty is usually defined in a broader way, as a state of unknowing where the individual lacks complete knowledge of a situation (Saunders et al. 2015). This unexplained variation can be partly caused by measurement errors, and partly by the lack of understanding about cause-and-effect relationships. In the case of CSSs, much of the uncertainty is caused by human and social influences or organisational conditions that make systems' performance difficult to predict and control (Böhle et al 2016).

In highly complex projects, due to the combination of structural complexity and uncertainty, the outcomes are said to be emergent rather than resultant (Hollnagel et al. 2015). This is the case, for instance, of making-do waste (Formoso et al., 2017). It is difficult or even impossible to explain what happens as a result of known processes or developments. Emergent outcomes are not additive, not predictable from knowledge of their components, and not decomposable into those components (Hollnagel et al. 2015).

Moreover, complexity may have an impact on the difficulty to understand and describe the system under consideration, and therefore, depends on the perception of the observer (Klir, 1985). A system is called tractable if it is possible to follow and understand how it functions. It means that the performance of that type of system is highly regular, its description is relatively simple in terms of parts and relations, with easy-to-understand details of how the system works (Hollnagel et al. 2015).

WHAT ARE THE IMPACTS OF SLACK?

There are some intended impacts of slack, i.e., expected or accounted for, while some impacts are unintended. Both can be either desirable (positive) or undesirable (negative) (Parks et al. 2017). Risk management is a discipline that considers a wide range of expected and unexpected events, to support decision-making in order to reduce the probability of adverse effects. In CSSs, predicting emerging events is a challenge, and slack can be regarded as a key risk mitigation strategy. Construction project risks may be tacitly accounted for in a fragmented manner in managerial processes such as those related to procurement, design, quality, safety, and production planning and control. Production teams also carry out risk management in everyday work when making decisions on the spot to assess trade-offs and prioritize the allocation of finite resources – e.g., when considering the risks of working overtime to complete an activity. This notwithstanding, Love and Matthews (2020) claim that systematic risk management is not widely used in construction projects

Four main categories of positive impacts of slack were identified in this investigation: (i) Resilience: is the intrinsic ability of a system to adjust its functioning prior to, during, or following events (changes, disturbances, and opportunities), so that it can sustain required operations under both expected and unexpected conditions (Hollnagel et al. 2015). (ii) Reliability: is the ability of a system and its components to perform required functions under stated conditions for a specified period of time (Rausand and Høyland, 2004). (iii) Robustness: is the preservation of particular characteristics despite uncertainty in the components or in the environment (Saurin, 2017). It reflects the ability of a system to maintain functionality when exposed to a variety of external or internal conditions and disturbances. Robustness is observed whenever there exists a sufficient repertoire of actions to counter perturbations (Whitacre and Bender, 2010). This concept is associated with the resistance and strength of a system. (iv) Flexibility of output is concerned with adapting products to fulfil specific customer requirements, without incurring high transition penalties or large changes in performance outcomes (Petroni and Bevilacqua, 2002), being strongly related to the mass customisation strategy. This capability demands several changes related to marketing, design and operations, but several types of slack may be necessary to make such changes feasible, e.g., redundant design, multi-functional teams. Those positive impacts will affect the performance of construction projects, potentially improving productivity, value generation, project duration, and image of the company for customers. From the perspective of the Lean Production philosophy, a negative impact of slack is the occurrence of waste. In this philosophy, waste is concerned with the occurrence of non-value-adding activities, i.e., activities that take time, resources, or space but do not add value from the perspective of the final customer (Ohno, 1988). Formoso et al. (2020) suggested that, instead of singular waste events, it is reasonable to expect chains of waste, i.e., chains of causes and effects in which one waste leads to another. Some types of slack can be related to waste, such as inventory of materials, work-in-progress, and unproductive time. The elimination of waste has been a driver for improvement, allowing problems that represent improvement opportunities to be identified (Ohno 1988). Therefore, slack as a potential category or source of waste should be measured and reduced, as part of continuous improvement programs.

Figure 1 presents the map that was produced based on the concepts and definitions investigated in this research work. It is divided in three zones: (i) superior (why slack is needed?); (ii) middle (what is slack?); and inferior (which are the impacts of slack?). Connections between the concepts and taxonomies are also represented in the map.

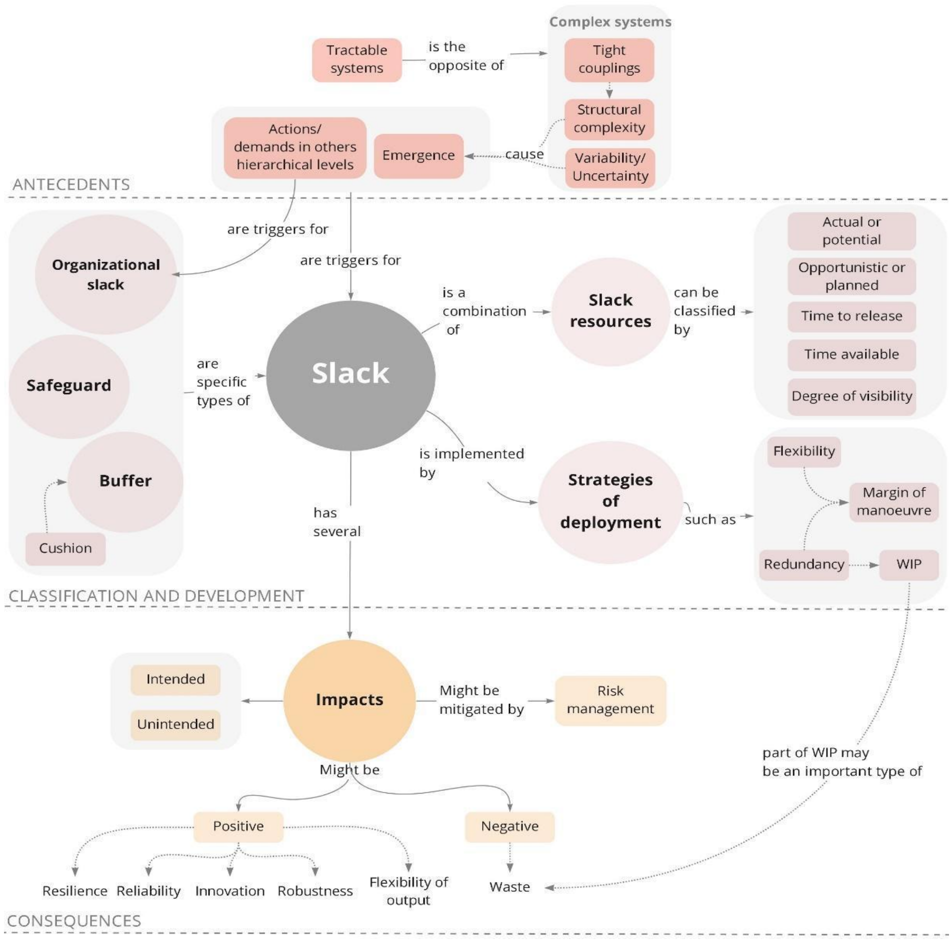

Figure 1: Concept Map

DISCUSSION AND CONCLUSIONS

Although the many notions of slack and buffer discussed seem disparate, there is a clear pattern. They can be clustered into two groups, based on the underlying conceptual framework on production. On one hand, discussions on buffers are related to a (natural) science understanding of production. On the other hand, most discussions on slack are based on seeing production as a CSS. The scientific understanding of production has been spearheaded by Spearman and Hopp (2020), which is strongly based on the queueing theory conceptualisation of production. Production is represented through flows of materials (or information). The central problem of production, as identified in Factory Physics, is uncertainty, in terms of flow and process variability. To cope with variability, there are only three countermeasures: inventories (buffers), more capacity or time (needed to produce one item). Out of these, buffers are the most important way to mitigate against variability, and mathematical models allow the optimal positioning and sizing of buffers.

Now, is this kind of (allegedly) scientific approach to production sufficient for advising on how to cope with uncertainty in production? In closer analysis, it turns out that the scientific model of production is an idealisation, where at least the following features have been abstracted away: (i) Production is modelled as a closed system, except for incoming and departing materials and information. Uncertainty is defined narrowly in terms of material and information flows. A production system is open to the world in many other ways, and vulnerable to uncertainty therein; (ii) Production is modelled as a natural science phenomenon. The usually unavoidable ingredient in production, human beings, are abstracted away, except for some buffer design methods that consider some specific types of human behaviour, such as student syndrome and Parkinson's law. In so doing, also the abilities to learn, to collaborate, and to invent new strategies for coping with uncertainties are abstracted away; (iii) The behaviours of flows and workstations are expected to be mutually independent, except in the way prescribed in the model. However, the inherent variability of a workstation may be influenced by the amount of the related buffer; (iv) The model contains a pre-determined set of behaviours and moves that a part can take. However, through human agency, new moves can be invented: the missing of one part can be encountered through making-do (Formoso et al., 2017). In turn, making-do may lead to unexpected outcomes, through emergence.

Thus, this scientific approach to production is partial. Still, it is often useful as a first analysis or baseline, and useful knowledge about the basic behaviour of production systems has been generated through it. However, for a comprehensive analysis, production needs to be conceptualized as a CSS. Then, the following features are taken into consideration: (i) Production is conceptualised as an open, evolving system, covering all uncertainties and risks from the environment of the system as well as the possibility of change, learning and creativity; (ii) Human beings, with all their capabilities, are included in the analysis; especially, uncertainty can be encountered through resourcefulness of employees or through organisational means; these forms to mitigate uncertainty are often called slack; (iii) The internal relationships between different phenomena in production are taken into account, to the extent possible; and (iv) The possibility of emergence of new outcomes is taken into account, to the extent possible.

This conceptualisation provides a different perspective for the analysis and design of production systems, in contrast to the seemingly rigorous causal theories offered by the scientific model of production. It extends the understanding of slack and related constructs, by considering the impact of different types of complexity in construction projects. These two conceptualisations should not be understood as competitors, but rather the scientific model of production should be positioned as providing one form of partial analysis when production is understood in a broader way, as a complex socio-technical system.

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