PPI Technical Guide 01 - Version 01

Five Levers Of Production System Optimization

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PROJECT PRODUCTION INSTITUTE

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INTRODUCTION

The purpose of this technical guide is to drive better project outcomes by enabling engineering and construction professionals to clearly understand the five levers of production system optimization, their interrelationships, and how they can effectively be applied when designing, optimizing and controlling production systems based on given objectives. This guide also contrasts this perspective with that of conventional project management as to clearly expose the gap in the current project delivery approach.

CONVENTIONAL PERSPECTIVE

The conventional perspective for the delivery of capital projects is based on the premise that the overall time (duration), cost and amount of cash tied-up during a project is a function of scope & quality, schedule and resource use (Figure 1). The relationship among scope & quality, schedule and resource use, known as the Iron Triangle, is typically seen as a trade-off relationship where at least one has to be sacrificed in order to improve the other(s).

Using this thinking, sample scenarios may be as follows:

1. If the amount of resources is reduced, while the scope & quality remains constant, the schedule must be extended
2. If the schedule is compressed for the same scope & quality, the amount of resources must be increased, and
3. If the schedule is to remain the same with reduced resources, the scope & quality must be decreased.

However, any seasoned project manager will say there is more at play as there are projects where scope & quality and schedule are improved with less resources, while there are projects where scope & quality and schedule deteriorate, even if more resources are added. Therefore, these situations and relationships can only be explained by introducing additional variables.

Figure 1. Levers of Project Management for Cost, Time & Cash

FIVE LEVERS DEFINED

In contrast with the above conventional perspective, the use of a production system framework for the delivery of capital projects allows for the application of Operations Science (OS) as the technical basis to map, model, analyze, optimize, control and improve project production system performance. As a result, the performance of a production system is governed by five production-based levers, as seen in Figure 2: (1) product design instead of scope and quality, (2) process design instead of schedule, (3) capacity (an element of resource that performs the work), (4) inventory (an element of resource that the work is done to), and (5) variability. The definition of each lever is as follows.

1. *Product Design*: The design of the asset, its systems, assemblies and parts including standardization, modularization and physical decoupling/interface mechanisms.
2. *Process Design*: The sequence of production operations; how and where work will be performed to produce the asset including how work is chunked and batched, the technical requirements, technology and automation used for work execution, policies and control mechanisms. Process design is not a schedule.
3. *Capacity*: The maximum average rate at which the items/units/tasks/products can flow through a process or system. Capacity contributors include labor, equipment and space required to perform the work. The throughput of a production system is determined by the lesser between demand and capacity.
4. *Inventory*: The accumulation of entities that occurs anywhere within and/or between processes (flows). Inventory between two or more supply and demand flows is called stock while inventory within a flow is called work-in-process or WIP.
5. *Variability*: Any dissimilarity between specific instances of a particular operation or process, particular entity output from an operation, or a particular demand. The dissimilarity may manifest itself in terms of attributes of the entities/operations or in the timing of those entities/operations.

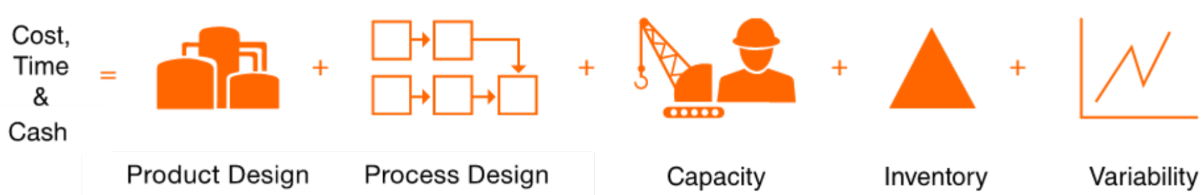


Figure 2. Five Levers of Production System Optimization

As can be inferred from the above descriptions, these levers are interdependent. Therefore, best results cannot be achieved by optimizing each lever independently, although many have tried and continue to do so.

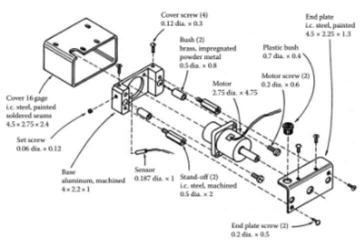
One example in the engineering and construction industry is the trade-off made, often unintentionally, to maximize capacity utilization to achieve the lowest cost. To achieve this, work groups, departments, organizations and their project teams use a large inventory of materials and information to protect their work from upstream variability. At a meta level, fabrication protects itself from engineering, logistics from fabrication, construction from logistics and in construction, one trade from the previous. At a more detailed level, something similar occurs as welding protects itself from cutting, testing from welding, etc. This belief across the industry, that getting the highest utilization of labor, equipment and space, often using inventory as the means to accomplish this, will also result in achieving the minimum duration at the lowest cost, is simply flawed. Yet, billions of dollars are constantly lost globally through the application of this thinking. Some of this suboptimization may be based on the commercial interests of organizations that are responsible for a limited scope of the overall project. However, due to the frequency in which this behavior is observed within a single organization's scope with results being exactly opposite as intended, we conclude that the implications of these decisions are not widely understood.

The implications of this strategy manifest through questions like: "How can our productivity numbers be increasing, but the overall project is falling further behind?" Unfortunately, decisions that suboptimize one lever are not only made regularly, but without a clear understanding of their unintended consequences to the behavior of the project production system; more specifically, without understanding how a decision about one of the levers affects the others and causes a specific behavior in the system.

INTERRELATIONSHIP

Optimizing the design of a Project Production System (in operation or not) must take into account the implications of decisions associated with one lever and how that will impact the other four levers. Therefore, understanding how they are interconnected, including trade-offs that exist between them, is key to making optimal decisions related to the ability of the production system to deliver on certain demand (e.g., project objectives).

An area that many have previously explored and studied is the relationship between product and process design, as is the case of Design for Manufacture and Assembly (DfMA) as shown in Figure 3. However, the impact product and process design decisions have on the other three levers (capacity, inventory and variability) is something that many either miss or do not clearly understand. One other opportunity that many seem to miss is the incorporation of existing capacity, inventory and variability as constraints for the product and process design (what defines the "true" design space for the system).



Results of DFA Analysis for the Motor Drive Assembly Original Design (Figure 1.8)

	No.	Theoretical Part Count	Assembly Time (s)	Assembly Cost (¢)[a]
Base	1	1	3.5	2.9
Bushing	2	0	12.3	10.2
Motor subassembly	1	1	9.5	7.9
Motor screw	2	0	21.0	17.5
Sensor subassembly	1	1	8.5	7.1
Set screw	1	0	10.6	8.8
Standoff	2	0	16.0	13.3
End plate	1	1	8.4	7.0
End plate screw	2	0	16.6	13.8
Plastic bushing	1	0	3.5	2.9
Thread leads	—	—	5.0	4.2
Reorient	—	—	4.5	3.8
Cover	1	0	9.4	7.9
Cover screw	4	0	31.2	26.0
Totals	19	4	160.0	133

$$\text{Assembly index} = \frac{4\times3}{160} = 7.5\%$$

[a] For a labor rate of $30 per h.

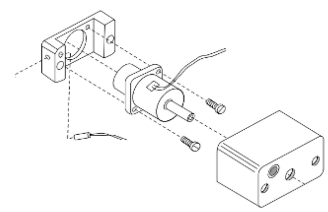


TABLE 1.3

Results of DFA Analysis for the Motor Drive Assembly Redesign (Figure 1.9)

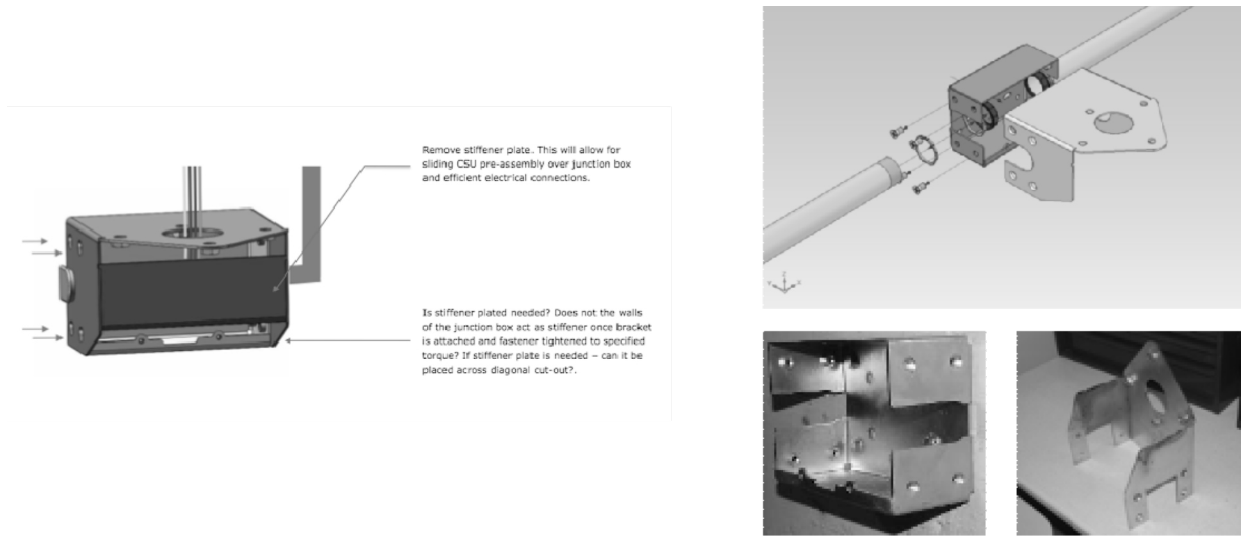
	No.	Theoretical Part Count	Assembly Time (s)	Assembly Cost (¢)[a]
Base	1	1	3.5	2.9
Motor subassembly	1	1	4.5	3.8
Motor screw	2	0	12.0	10.0
Sensor subassembly	1	1	8.5	7.1
Set screw	1	0	8.5	7.1
Thread leads	—	—	5.0	4.2
Plastic cover	1	1	4.0	3.3
Totals	6	4	46.0	38.4

$$\text{Assembly index} = \frac{4\times3}{46.0} = 26\%$$

[a] For a labor rate of $30 per h.

Figure 3. Example of Design for Manufacture and Assembly (Boothroyd and Dewhurst [1])

Figure 4 shows an example of the application of DfMA for the installation of electric vehicle infrastructure. More specifically, how the original design of a bracket that connects a charge spot unit to a vertical surface was redesigned to improve the design of not only the onsite assembly process, but also to incorporate the possibility of off-site assembly and to be able to compress cycle times.



ORIGINAL DESIGN

DMFA REDESIGN

Figure 4. DfMA Application for Electric Vehicle Charge Unit Bracket

Currently, the engineering and construction industry seems to be very enamored with the potential benefits that product standardization and modularization provide. In terms of product standardization, the obvious benefit for a project or across many projects is that it eliminates much of the design and engineering efforts, as they only need to be done once (implications to the process design). Moreover, standardization also eliminates the need to coordinate sequence of fabrication and delivery to the site as one can fit anywhere (implications for inventory). In addition, it removes variability that arises from product variety (implications for variability). All these decisions may result in reduced cost, time and cash-tied up, but with one “small” caveat: whether the standard product meets the needs of the end-customer. There are many examples throughout history of how a custom product has taken huge market share from companies that provide standard products, e.g., early days of Ford vs. General Motors, McDonald’s vs. Wendy’s, etc.

However, in the world of projects, where the production environment is not standard, localization efforts to make the standard design fit into a non-standard environment may over-eclipse all the gains of standardization through increased complexity of the localized product design, process design, capacity, inventory and resulting variability. Standardization must therefore be done at the appropriate level of the product structure, e.g., component, sub-system, system or asset, to allow for optimization of the overall production system, while meeting the expected business and project objectives.

The purpose of modularization is not the same as standardization nor is it the same as offsite fabrication, although the industry tends to use the concepts interchangeably. Modularization chunks the overall product into modules or assemblies, which may or may not be physically identical, to be fabricated and assembled onsite or offsite with the intent to minimize the level of effort and capacity needed for final assembly. However, and especially in the case of offsite assembly, each module has to be transported, sometimes over a long distance across continents, to its position for final assembly (implications for the process design) so it must be made structurally sound using additional elements to withstand the lifting and vibration that occurs during loading, transportation and offloading (implications for the product design)Moreover, and in order to optimize transportation (e.g., the requirement to fit on a given type of transport, modules are typically designed to have higher density than a regular stick-built design (implications on the product design. Once modules reach this level of complexity, it is common to hear that there are only one or two places in the world that can make the modules (implications for capacity). As modules become unique (engineer-to-order items), even if they are made with standard make-to-stock and make-to-order items, inventory cannot be used as a strategy (implications for inventory.

There are also important interrelationships amongst variability, capacity and inventory that must be discussed. A production system without variability, both in demand and production, simply does not exist. The fact is that all production systems, including those of projects, will contain some amount of variability. Besides being a fact of the project lifecycle, sources of variability can be differentiated as beneficial or detrimental. An example of beneficial variability is non-standard products to facilitate the maximum revenue opportunity (which again raises the question that many organizations are asking: "standardization at what cost?". For example, a company that designs and builds highly custom buildings while effectively managing high variability can be profitable because customers often don't want standard buildings. On the other hand, an example of detrimental variability is any rework due to a quality deficiency or out of sequence work, which may result in Earned Value yet also adds additional cost, time and causes less than optimal use of capacity and inventory.

Regardless of the source, variability will always degrade production system performance, causing less throughput and longer cycle time for a given capacity, which in fact results in more cash tied-up in the system or additional cost because of the need to increase capacity to meet demand, such as overtime or additional shifts. The implications of variability can be clearly understood by examining Figure 5, which depicts the impact of work-in-process (WIP and variability on throughput and cycle time for a given production system (a graphical representation of a fundamental Operations Science relationship, Little's Law, which is stated as Cycle Time = WIP/Throughput. The Project Production Institute [2] defines WIP as "the set of entities that are partially transformed within any given process and does not include stock inventory, which is composed of completed entities". Hopp and Spearman [3] define cycle time as "the average time from when a job is released into a station or line to when it exits". In Figure 5, the solid lines represent throughput (green and cycle time (blue under no variability, while the dotted lines represent those for a given level of variability.

The larger the variability, the larger the degradation (vertical distance from the solid to the dotted line. In practical terms, this means less throughput and longer cycle time for a given level of work-in-process and capacity.

Therefore, minimizing detrimental variability, while allowing for beneficial variability to the extent that the trade-off is beneficial to the business, is critical to improving the performance of a production system while maximizing profitability of the business.

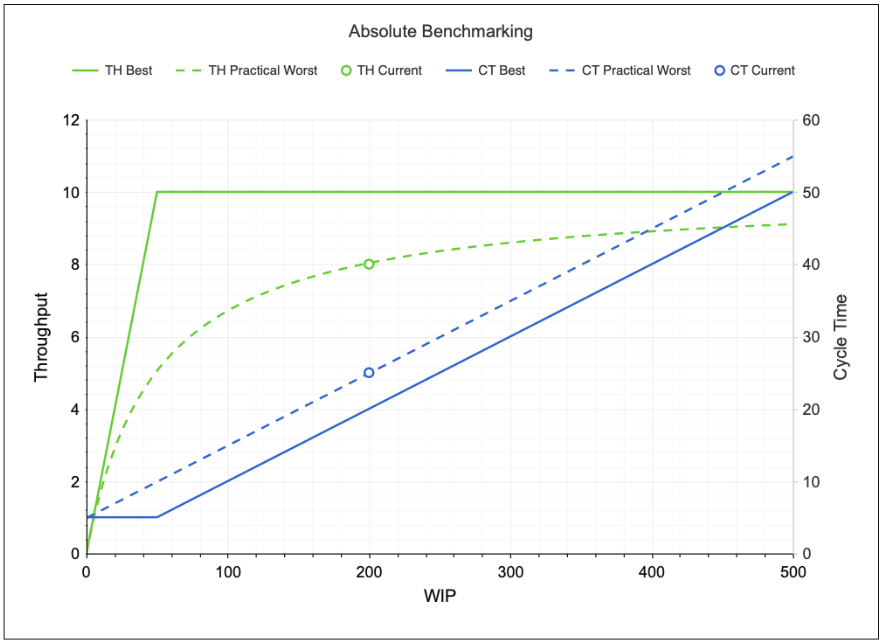


Figure 5. Implications of WIP and Variability on Throughput and Cycle Time

Variability between demand and supply can be absorbed using different types of buffers, i.e., inventory/time and capacity. If there is variability in demand and / or supply and inventory cannot or will not be used to absorb it, variability can be absorbed by additional capacity. If there isn't enough inventory or capacity to absorb the variability, it will be absorbed by additional time, i.e., tasks or items will be back-ordered. A back-ordered item or task is late and results in additional time which can be thought of as negative inventory. If a task or item is completed before it is needed, it is inventory (could be physical or virtual). Inventory and time are the two different forms of the inventory/time buffer. Buffering with inventory might be a legitimate strategy for make-to-stock items that have sufficient inventory in the supply network as long as "cost" associated with holding and handling inventory, including risk of obsolescence, is less than the cost of idle capacity. However, for engineer-to-order items where there is no existing inventory in the supply network, these are essentially backordered, and therefore, it takes time to create inventory. If a project is using an inventory of engineer-to-order items to buffer variability, a careful examination of the trade-offs is required, as time and cost saved by having inventory might be less than the time and cost it takes to build-up and manage the inventory. Additionally, many organizations that attempt to leverage standardization to improve project delivery but do not manage the variability between supply and demand see a large amount of inventory built up between demand and supply resulting in additional time and cash tied-up.

Another insight Little's Law provides is that the amount of WIP determines the cycle time. Basically, the higher the WIP, the longer the cycle time. If there is a desire to reduce the cycle time for faster Return on Invested Capital

(ROIC, maintaining the right amount of WIP in the system that allows demand to be met with minimal cycle time is definitely critical because having too little will produce a big drop in throughput, resulting in missed demand and wasted capacity (as seen in Figure 5. On the other hand, having too much WIP will result in a minimal increase in throughput (assuming there is no blocking effect where increased WIP actually reduces throughput, while cycle time increases, i.e., cash is tied up longer in the production system, not to mention loss of revenue.

As described above, due to the many interdependencies, project professionals must consider all five levers to properly design a production system or to improve an existing production system. However, this does not mean adopting a trial-and-error approach, as Operations Science [2] provides the basis to map, model, optimize and improve production systems.

[2] The Project Production Institute defines OS as “the study of the transformation of resources to create and distribute goods and services. OS focuses on the interaction between demand and production and the variability associated with either or both. OS also describes the set of buffers required to synchronize demand with production.”

APPLICATIONS

The five levers can be applied to the design and optimization of any project production system, independent of its configuration, complexity and level of criticality. To illustrate an application, this section introduces the case of a rebar production system and how the five levers were used to make decisions about the desired behavior to not only meet project objectives, but also to address given project constraints.

This production system was one of many needed to support the major expansion project of a very busy and highly secured operating facility with limited space available onsite to hold stocks of materials. Based on this constraint, an analysis of the demand (total quantity and required daily rates) determined project teams could only have two days' worth of materials, i.e., enough material to support today's and tomorrow's work, onsite at any given time. The implications were that all variability could not be absorbed by inventory alone.

Given these conditions, the design of the overall production system incorporated a couple of nearby facilities (capacity) to buffer the site from variability coming from the supply network. This included the offsite fabrication and assembly of rebar (capacity) and storage of the necessary volume of raw materials (inventory) for production of cut and bent rebar and rebar assemblies.

Due to site conditions and the required rate of installation, the project determined that assembly of rebar cages would be delivered to the point of installation and rapidly installed. Since all rebar cages could not be standardized, design guidelines that incorporated fabrication and logistical constraints were developed to ensure every design was fabricated, delivered and installed optimally. This is a great example of capacity impacting product design rather than capacity being an afterthought once the design is completed.

Figure 6 shows the design guidelines for the rebar production system. CLC and Ascot Road are the two rebar cage fabrication locations close to the project site.

Design Guidelines

- Lead time for CLC requires a 3 day turn around
- Fabrication within ASCOT road requires a 5 day turn around
- Typical width shall not exceed 2.85m
- Width's over 2.75m requires longer lead times due to associated permits
- Height must not exceed 3.35m
- Length must not exceed 10m
- Weight must not exceed 8 tonne for CLC and 3 tonne for Ascot road
- Exceptions to guidelines are to be notified on a 2 week look ahead and will be assessed on an individual basis
- All pre-assemblies shall fit to standard jig dimensions - 10m x 3m
- Maximum bar length to be 12m
- Maximum bent bar shall be contained within an imaginary rectangle, the shorter side of which shall not be longer than 2.75m to enable transportation
- Prefabricated rollmat shall have one bar diameter, one bar spacing and one bar length

Figure 6. Rebar Production System Design - Guidelines Example

In addition, close attention was paid to the design of the production process, which included operations such as detailed engineering for offsite assembly, fabrication, assembly, loading, transport, offloading and installation. The initial cycle time analysis indicated that a rebar assembly was taking six weeks to move through the production process from detailed engineering to site install. With such a long cycle time, plus the site conditions and uniqueness of the product design, it was unrealistic to rely on six-week forecasts to fabricate and deliver what the site needed. Based on this, efforts concentrated on reducing the cycle time by redesigning the end-to-end production process enabled by new technologies to make it fit within the reliability window of five days (process design).

However, in order to enable the supply of rebar to the right point of installation, in the right quantities and at the right time every time, the labor, equipment and space (capacity contributors) needed to be properly dimensioned with the goal of reducing cycle time rather than achieving the highest capacity utilization. As explained in the previous section, the pursuit of high capacity utilization beyond optimal utilization results in a rapid increase of cycle time, which creates a vicious cycle of requiring longer forecasts which leads to higher inaccuracy in demand and more unreliable supply, meaning ever-increasing chaos. Instead, the strategy was to use capacity as a buffer to accommodate for demand variability as well as to allocate a limited amount of trailers (physical WIP control) to transport the fabricated and assembled rebar to the site as in a milk run – a full trailer arrives today for installation tomorrow and returns empty to the nearby fabrication facility. In addition, daily production plans were created for installation with the goal of reducing demand variability to the extent possible for subsequent work, as well as fabrication and delivery of rebar assemblies. Although Figure 7 does not fully represent the interdependencies explained above and shows a limited number of the improvements that were implemented, it provides a summary view of how all five levers played a key role in designing an effective production system based on project objectives and site conditions.

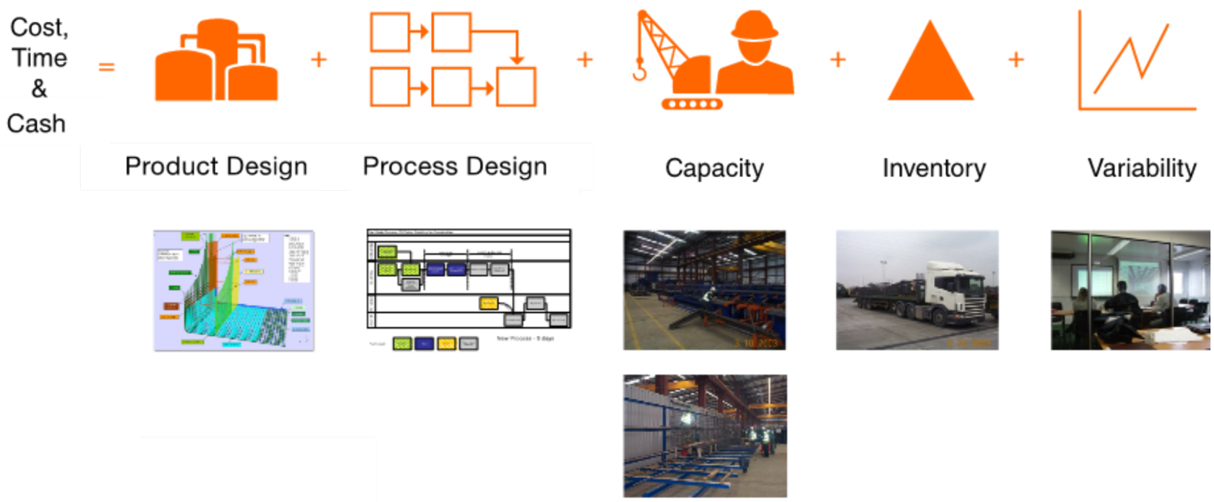


Figure 7. Application of Five Levers for Production System Optimization

GLOSSARY

Following are taken from the Project Production Institute's Glossary of Terms.

Capacity

The maximum average rate at which the items/units/tasks/products can flow through a process or system. Capacity is the upper limit of throughput. Having installed capacity above average demand allows the Stock Inventory and Backorder Time buffers to remain small. If the process had infinite capacity, there would never be either Stock or Backorders as the process could satisfy demand instantly.

Cycle Time

The average time from when a job is released into a station or line to when it exits. Cycle Time (CT) is related to Throughput (TH) and Work in Process (WIP) by Little's Law.

Inventory

The accumulation of entities that occurs anywhere within and/or between processes (flows). Inventory between two or more flows is called stock while inventory within a flow is called work in process or WIP.

Law of Variability

Increased variability always requires increased buffering when trying to synchronize demand and transformation.

Little's Law

The relationship between system throughput (TH), cycle time (CT), and work in process (WIP) as CT = WIP / TH. Cycle time is a dependent variable. WIP is a leading indicator of CT.

Modularization

In the construction industry, the process of completing subassembly packages of work which are then joined to the final assembly structure. A module could be a section of a house, living quarters for an offshore oil platform or a pipe rack. The practice of modularization in construction has commonly come to mean moving work away from the construction site. Modularization is independent of location. The common use of modularization as offsite work can cause significant degradation of project performance due to excess buildup of WIP and sequencing issues between module construction and onsite final construction.

Operation

An act that transforms one or more attributes of an entity or set of entities. Examples include manufacturing, services, transportation, or projects. An operation will require the use of one or more resources in order to perform the transformation. These resources include raw materials, subassemblies, components, labor, machines, information, intelligence, energy, fuel, etc.

Operations Science

The study of the transformation of resources to create and distribute goods and services. Operations Science (OS) focuses on the interaction between demand and production and the variability associated with either or both. OS also describes the set of buffers required to synchronize demand with production.

Process

A set of one or more operations designed to transform a set of entities into another form to achieve a particular purpose. A process may result in production of a physical product or completion of a service. A project is a collection of service and production processes. Examples of processes include production lines, construction projects, hospital operating theaters, insurance claims processing and Discrete Event Simulation analysis. Also called a Value Stream.

Process Design

The sequence of production operations, how and where work will be performed to produce the asset including how work is chunked and batched, the technical requirements, technology and automation used for work execution, policies and control mechanisms. Process design is not a schedule.

Product Design

The design of the asset, its systems, assemblies and parts including standardization, modularization and physical decoupling/interface mechanisms.

Production

The act of transforming or changing the shape, composition or combination of materials, parts, subassemblies or information to increase their value.

Production System

A specific or defined set of operations within a larger supply network or value chain that produces technical or physical output to satisfy an external demand.

Production System Definition

The purpose, objectives and constraints upon which the production system design is based.

Production System Definition Process

Setting forth business purpose and objectives for the project, establishing project objectives and identification of constraints upon which the production system design is based.

Production System Design Process

The practice of mapping, analyzing and optimizing the processes, resources and controls in accord with a set of given objectives.

Production System Optimization

The practice of mapping, modeling, analyzing and simulating a production system to achieve best desired performance. Key areas of focus for PSO are throughput, cycle time, use of resources (capacity and inventory) along with sources and implications of variability. PSO supports design of new production systems and improvement of existing production systems.

Productivity

Man-hours required per unit of work, productivity is the input divided by the output and is usually calculated for a finite time interval. It is also commonly referred to as a Unit Rate.

Project Management

The application of knowledge, skills, tools, and techniques to project activities to meet the project requirements.

Project Production Management

The application of Operations Science to map, model, analyze, optimize, control, monitor and improve project production systems.

Project Production System

The collection of production systems comprising the interconnected network of processes and operations that represent all the work activities to execute a project from start to finish.

Rate

A fixed ratio between two things. For production systems, rate is a measure of throughput or output and is stated as units per period of time or tasks per period of time.

Resource

A stock or supply of money, materials, staff, and other assets that can be drawn on by a person or organization in order to function effectively. An operation will require the use of one or more resources in order to perform the transformation. These resources include raw materials, subassemblies, components, labor, machines, space, information, intelligence, energy, fuel, etc.

Resource Types

Consumable resources do not become part of the entity. Examples include energy, lubricating oil, cooling water, etc. Non-consumable resources do not become part of the entity but are required and not consumed. Examples include information, plans, designs, CAD drawings, etc. Physical resources become part of the entity. Examples are raw materials, sub-assemblies, components, individual items, etc. Capacity resources are required to transform the entity but do not become part of the entity such as machines, labor, transportation.

Schedule

A procedural plan that indicates the time and sequence of each operation. In construction, a schedule is most often used to deterministically set milestones and completion dates for tasks and to monitor progress against those dates. Schedules are thereby inherently unreliable when coordinating activities because projects are not deterministic endeavors. In Project Production Management, the project schedule serves as a representation of demand and in turn, schedules result from the analysis of capacity utilization, variability, WIP and their associated control as governed by Operations Science.

Stock

A set of completed transformations or entities. As such the entities in stock are immediately ready to satisfy demand immediately. Since Demand is a flow and the Transformation Process is a flow, there will always be a stock between demand and transformation. However, since the demand for services is always backordered, such a stock will always be empty but will nonetheless function as a stock.

System

The word system is derived from the ancient Greek sustema and thence the Latin systema. Thus, it has two distinct sets of meanings, from which numerous specializations exist:

- A set of interconnected things or parts working together to form a complex whole e.g. a manufacturing assembly line consists of a series of manufacturing stations working together in an interconnected network
- A set of principles or procedures according to which something is done; an organized scheme or method e.g. the metric system, a set of rules in measurement or classification
- For the purposes of this glossary, we adopt definition (1) for use in phrases like “Production System” or “Project Production System” – a set of interconnected processes working together to form a complex whole.

Throughput

Measured as the average output of a production process (machine, station, line, plant) per unit time. Throughput is related to Cycle Time (CT) and Work in Process (WIP) by Little's Law.

Utilization

A measure of the fraction of time that a station in a production system is not idle. Utilization equals rate of arrivals to a station divided by the effective rate of the station. Utilization is also defined as the time used at a station divided by the time available at the station.

Variability

The term used to describe any dissimilarity between specific instances of a particular operation or process, particular entity output from an operation, or a particular demand. The dissimilarity may manifest itself in terms of attributes of the entities/ operations or in the timing of those entities/operations.

Variability – Types

Entity variation includes differences in any attribute such as size, color, hardness, density, quantity, quality, etc. Process variation includes differences in the output of the process itself such quality of service, application of the process, etc. Time variation deals with time to obtain or produce entities and/or services.

Variability – Beneficial

A change in operating parameters that improves overall project business case. For example, the unexpected arrival time of raw materials earlier than expected, can in the right circumstances, lead to an earlier than planned completion time for the project which may result in additional revenue generated by the completed project. Other examples of beneficial variability are the introduction of new technology or processes that improve overall project business case, e.g., new technology or product design, that allows more revenue to be generated by highly competitive products.

Variability – Detrimental

A change in operating parameters that worsens overall project business case. For example, rework due to quality issues increases costs and extends completion time. Other examples of detrimental variability are bad weather that causes work to be delayed or rescheduled, also potentially adding costs and extending completion times.

Work in Process

The set of entities that are partially transformed within any given process. WIP does not include stock inventory which is composed of completed entities. WIP typically accumulates while waiting for available capacity in front of an operation. Stock accumulates between two or more processes (e.g., finished inventory between a process and its demand).

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