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AVAILABILITY CLASSIFICATION FOR APPLICATIONS IN CONSTRUCTION PRODUCTION SYSTEMS: A REVIEW

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Milan Mirkovic

Consulting Experts System, Zrenjanin, Serbia

Abstract. *The aim of the paper is to improve availability classifications of components for application in construction systems. Construction production systems belong to project-based systems with serial-parallel structures with or without redundant components, and the availability function has a significant impact on the performance indicators of components and systems. The main indicators of function of the components are the availability, capacity, costs, and project time. A new approach to classification makes it possible to choose the most appropriate methodology for assessing component availability in the bidding phase, and managing company's machine park. The new classification approach was tested on a practical example. The results obtained confirmed the justification for extending the classical approach to the classification of the availability of components.*

Key words: *availability, construction component, component indicators, production system*

1. INTRODUCTION

Availability is key when designing industrial systems. The capacity of the (system) components and the system as a whole can be changed from a state of full operability to failure and reduced operability. The status of the components may affect the capacity, unit costs, and total costs, and project time. Estimating the availability of components in such situations is of great importance in the *bidding phase* [1], [2].

According to Eq.1, the general measure of availability is a *ratio* of usable/operational time to a total given period or cycle time [1], [2].

$$Availability = Operational\ Time/Time\ Period \tag{1}$$

Production systems exploit sets of elements and the interrelationships between them and their characteristics, in order to perform a function. This means that the connections between the components and subsystems are in accordance with the specificity of the production system, i.e. technological process.

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Corresponding author: Milan Mirkovic
Consulting Experts System, Takovska 69A, 23000 Zrenjanin, Serbia
E-mail: milan.mirkovic@highways.rs

Construction production systems are a specific type of industrial system where temporality and uniqueness are key. This means that there are no two or more identical construction projects. Each construction project has a clearly defined start and, end of work in the goals set. Furthermore, there is no system for completing construction projects with an identical organizational structure [2].

Construction systems in the field of civil engineering, where highly mechanized work is involved are highly complex in terms of the production system's availability. This complexity is reflected in the specifics of the environment in which the building is performed, frequently with unknown total costs, functioning in open spaces, with production lines that are significantly distant from each other, variable durations in the construction time (from several months to several years), and fairly specific contractual relations between the investor and the contractor. [2].

The availability of system components, subsystems, and systems as a whole affects the probability of whether the system will operate successfully and the range of permitted deviations of the set criteria function in the given time and given environmental conditions. Their availability is predicted, estimated, and evaluated in direct relation to the bid level of the system (general, conceptual, and detailed bids) [2].

The significance of the availability function is gaining in importance in designing and analyzing production systems, and this is reflected in the simultaneous analysis of the reliability, availability, and maintainability.

Availability is a fundamental aspect in the performance of the maintained (repaired) systems. Also, availability is an indicator of the probability that the system/component will function satisfactorily, at any time when used under the specified conditions, where the time considered refers to the time of operation and the downtime[2].

The first classification of availability resulted in a division into two groups in terms of application to military components and systems [3]-[5]. The next extensions of the definition and classification were made with regard to application to military systems, also [6], [7]. In the 1980s, availability was applied to production systems, but without any improvement in definitions, nor in any additional knowledge about their classifications. The first works in the area of reliability, availability, and maintainability with new classifications of availability from the aspect of construction systems emerged in 1990s [8], [9]. Expanding the definition of production availability from application to construction components and systems created the conditions for additional research in this field [10]-[12].

The research of a large number of published works, professional literature, new standards, guidelines, and practical experience, influenced the selection of the subject research, i.e. modern approach for defining availability of construction components.

2. Literature Review

The first works on the reliability of components and systems emphasized the need for the maintenance criteria. Research in the field of system's maintenance in terms of the maximizing reliability values resulted in two maintenance approaches: reliability-centred maintenance (RCM) and availability-centred maintenance (ACM). These two approaches positioned availability as a measure of the reliability of the maintained systems. Maintenance criteria, with all the necessary logistical and administrative activities, opened a new chapter in an integral approach to reliability and availability analysis;

maintainability (M). The first works (1960s) in the field of integral access (RAM-Dependability) emphasized the importance of the availability function.

In the first availability classifications availability was simply classified into [3], [4]:

- A (t) – instantaneous or point availability
- A (T) – average up time or mean availability
- A (∞) – steady state availability

Further research in the field of repairable systems emphasized the need to divide the availability into two groups [5] in relation to:

- the time interval
- the downtime type

2.1. Availability as a function of the time interval

2.1.1. *Instantaneous or point availability – A (t)*

Instantaneous or Point Availability represents the probability that the system will be in operational condition at random time "t", that is, in the specified time interval [0, T]. Unlike reliability, current availability includes information regarding maintainability. In this case, the system will be operational at a time if the following conditions are met:

- The component functioned correctly from "0" to "t" with the probability R (t)
- The component has functioned correctly since the last repair in the "u" time, where:
  - 0 <u <t, with probability:

$$\int_0^t R(t-u)m(u)du \tag{2}$$

Where:

$m(u)$ - function of system recovery density

According to Eq. 3, the instantaneous availability is the sum of the two previous probabilities [5]:

$$A(t) = R(t) + \int_0^t R(t-u)m(u)du \tag{3}$$

2.1.2 Average up time or mean availability – A (T)

Average up time availability or mean availability is the proportion of time in system operation or the expected probability of system availability at time [0, T] [5]:

$$A(T) = \frac{1}{T}\int_0^T A(T)dt \tag{4}$$

2.1.3 Steady State Availability – A (∞)

Steady state availability is the limit value of the instantaneous availability of the function during the "t" time which tends to infinity:

$$A(\infty) = lim_{t\to\infty} A(t) \tag{5}$$

In industrial systems, as well as in construction machine systems and plants for the creation of project positions, steady state availability is most often used due to the sufficiently high total time (t) of the functioning of the system. In such situations, the time tends to infinity, thus it follows that the failure rate (λ) and the repair rate (μ), are the constant value, i.e.:

$$\lambda(t) = \lambda \tag{6}$$

And:

$$\mu(t) = \mu \tag{7}$$

In this case, it follows that:

$$A(t) = \frac{\mu}{\lambda + \mu} + \frac{\lambda}{\lambda + \mu} e^{-(\lambda+\mu)t} \tag{8}$$

Where:

$$A(\infty) = \frac{\mu}{\lambda + \mu} \tag{9}$$

Due to the status of the component, it follows:

$$A(\infty) = \frac{MTTF}{MTTF + MTTR} \tag{10}$$

Where:

MTTF - mean time to failure

MTTR - mean time to repair

The mean time to repair has been redefined in recent papers in this field as the mean time to restore (MTTRS) due to the additional time (ALDT) after the active component has been repaired and put back it into operation. It means that: MTTRS = MTTR + ALDT. According to Eq. 10:

$$A(\infty) = \frac{MTTF}{MTTF + MTTRS} \tag{11}$$

2.2. Availability as a function of downtime type

Availability as a function of downtime type, as well as availability as a function of time interval has its own classification [5]:

- A (i) - inherent availability
- A (a) - achieved availability
- A (o) - operational availability

2.2.1. Inherent availability – A (i)

Inherent availability is defined as the probability that the system in use under the given conditions will function satisfactorily at a given moment of time, without taking into account any planned or preventive repairs. The inherent availability relates only to the time of corrective repair of the system, assuming 100% availability of the personnel and repair equipment. This type of availability represents the fulfilment of the requirement for achieving the expected performance of the planned downtime in operation. The availability of the system component is[5] :

$$A(i) = \frac{MTTF}{MTTF + MTTR} \tag{12}$$

2.2.2. Achieved availability – A (a)

Achieved availability identifies the timing of preventive and corrective maintenance. It is determined by a detailed design closely defines the type, quantity, and timetable of equipment for timely repairs i.e. maintenance. The achieved availability can also be considered as a steady state availability which only considers the time of active preventive and active corrective repairs. Achieved availability can be expressed as the following equation[5]:

$$A(a) = \frac{MTBM}{MTBM + \overline{M}} \tag{13}$$

Where:

MTBM - mean time between maintenance
$\overline{M}$ - mean time of maintenance

This definition meets the requirements for reaching availability when downtimes are planned. The goal of availability of the repaired (maintained) system is to find extreme values of the function, in order for the system to be at the required level of operation. The resulting availability depends on the production system design that determines all possible scenarios during its operation and maintenance strategy.

2.2.3. Operational availability A (o) - basic definition

Operational availability is a measure of the average availability over a period of time and includes all experienced sources and causes of delays as well as downtimes (administrative, logistic, organizational, etc.). Operational availability is the availability through which the system has passed, and is based on current events that are taking place in the system.

Preliminary availabilities are based on estimates, as well as the models of the system that is in the function of statistical distribution of time. Operational availability can be expressed as the relationship between the time in operation and the total time of the system. Mathematically, operational availability is determined by Eq. 14[1] - [6]:

$$A(o) = \frac{MTBM + Ready\ Time}{(MTBM + ReadyTime) + MDT} \tag{14}$$

Where:

MDT - mean down time
Ready Time - component is available and ready to operate

Operational availability is the lowest limit of performance that is experientially determined (by observing the system in operation) for the given projected capacity and other pre-specified criteria. When there is a high probability of the availability of a system with which the system will achieve the set goal, then the construction technology developer expresses the desired availability, i.e. *project availability*.

2.2.4. Operational availability - new approach

Additional divisions have been made with the new approach for defining operational availability within MTBM and MDT times. Namely, MTBM has been divided into the time when the component is available and in operation. MDT has also been divided into TCM, TPM and ALDT, i.e. according to Eq. 15 [6], [7]:

$$A(o) = \frac{OT + ST}{OT + ST + TCM + TPM + ALDT} \tag{15}$$

Where:

MDT – mean down time
OT – operational time
ST – standby time
TCM – total corrective maintenance time
TPM – total preventive maintenance time
ALDT – total administrative and logistic time

Comparing expressions 14 and 15 reveals the following:

$$MTBM + ReadyTime = OT + ST \tag{16}$$

While,

$$MDT = TCM + TPM + ALDT \tag{17}$$

This approach for defining operational availability provides a more detailed insight into the availability of the component in terms of the causes that led to the state of hibernation of that component. Also, different costs and capacities are associated with each given time [2].

2.3. Production availability

Due to its specific definition and similarity with operational availability, i.e. the availability of the system through which it passed, production availability (PA) deserves a special analysis approach.

Defining production availability differs from the previous definition of availability in terms of the time intervals and the type of delays. The production availability of the technological process is analyzed through efficiency, utilization, and basic availability of the following capacities and the states in which the component can be found [7]:

- maximum capacity
- nominal capacity
- reduced capacity
- stand-by state
- state of failure

Production (equivalent) availability (PA) can be defined as "the ratio of the equipment's equivalent operational time to a total given period, during which a system achieves a process output that is equivalent to its maximum dependable capacity" [7], [12]. Thus:

$$PA = \sum \left(\frac{To \times n \times MDC}{T \times MDC} \right) \tag{18}$$

Where:

To – time of component function at maximum capacity
MDC – maximum dependable capacity
n – ratio of process output
T – total time period

Equation 19 can be adopted as the *basis* for a proposal of the production *availability* model for *construction components*:

$$A = \frac{\sum_{i=1}^{n_o} h_i \times n_i}{\sum_{i=1}^{n_o} h_i} \tag{19}$$

Where:

h_i – time intervals for the available component with maximum, reduced and zero capacity
n_i – ratio between the actual (q_{act}) and maximum construction capacity (q_{max}) of the component

2.4. Availability standards

Because of the importance of the reliability, availability, and maintainability, as well as the related attributes, there are hundreds of associated standards. Some are general but more are specific to domains such as automotive, aviation, electric power distribution, nuclear energy, rail transportation, and software. Standards are produced by both governmental agencies and professional associations, and international standards bodies such as:

- The International Electro technical Commission (IEC), Geneva, Switzerland and the closely associated International Standards Organization (ISO) - IEC 60050-191:2015
- International Standards Organization (ISO), Earth-Moving Machinery - Machine Availability Vocabulary - ISO 8927 - 191
- The European Committee for Standardization (CEN) - EN 61703:2016
- The Association Française de Normalization (AFNOR) - X60-500
- The British Standards Institute (BSI) - BS 4778

- The American National Standards Institute (ANSI) - ASTM F 2446 - 04 (2018)
- Deutsches Institute Für Normung (DIN) - DIN EN 61703:2017-8
- The Japanese Industrial Standards Committee (JISC)
- The Russian National Standards (ГОСТ) - Р 27000 - 2009
- The Serbian Institute for Standardization of Serbia (ISS) - SRPS EN 61703:2018
- Governmental Agencies – primarily in military and space systems (MIL STD-721B, MIL HDBK- 781, MIL STD-781C, DoD 32351- H, DoD - Guide for Achieving Reliability, Availability, and Maintainability - 2005
- Other national institutes for standardization

By analyzing all the definitions of availability, it can be observed that there are small differences that depend on the type of literature (military, industrial). For a comprehensive definition of availability for components and systems that are expected to be operational over a period of time (minutes, days, years), the following may be adopted:

Availability is the probability that a component/system, when used under stated conditions (operating mode and environment) will operate satisfactorily at a given point in time.

The basic mathematical definition of availability (A) is [7]- [12]:

$$A = \frac{UpTime}{TotalTime} = \frac{UpTime}{UpTime + DownTime} \tag{20}$$

2.5. Availability guidelines

Unlike standards, guidelines contain examples from practice with additional explanations. The most cited from the researched field are:

- The Institute of Electrical and Electronic Engineers (IEEE), New York, NY, USA, Standard Definitions for Use in Reporting Electric Generating Unit Reliability, Availability and Productivity - IEEE 762 - 2006
- The Society of Automotive Engineers (SAE), Warrendale, PA, USA - SAE J 199
- Verner Deutscher Ingenieure - Rihtlinen - VDI 3423
- AMT - The Association for Manufacturing Technology, Production Equipment Availability - A, Measurement Guideline, USA

IEEE definitions and classifications do not differ substantially from the above standards. VDI 3423 and AMT guidelines refer to production components and systems, and represent an important guidance from the point of view of the application to project-organized systems. They therefore merit a special approach in presenting definitions and expressions for the availability of components and systems.

2.5.1. VDI 3423 - Technical Availability of Machines (VT) and Production Lines

According to Eq. 20, the technical availability, the percentage of operational time during which a component/machine is available for production without any technical shortcomings is [13]:

$$V_T = 100\% - \left(\frac{T_T}{T_B} \times 100\%\right) = \left(1 - \frac{T_T}{T_B}\right) \times 100\% \tag{21}$$

Where:

T_T – technical downtime

T_B – occupied time

The technical downtime T_T is the sum total of all downtimes resulting from shortcomings in the design and construction. Examples of such shortcomings are [13]:

- inadequate quantity and quality of material
- poor design or construction
- poor documentation
- need for corrective maintenance
- waiting for spare parts
- waiting for service personnel
- test runs serving for fault location
- test runs after fault rectification

The occupied time - T_B is that time within the period under consideration for which any utilization of the machine or plant is planned. According to Eq. 21, [13]:

$$T_B = T_N + T_O + T_T + T_W \tag{22}$$

Where:

T_N – utilisation time

T_O – organisational downtime

T_W – maintenance time

The utilisation time - T_N is the time in which the machine operates in full capacity.

The organisational downtime - T_O is the sum total of all downtimes caused by organisational shortcomings:

- energy shortfall
- lack of work pieces
- lack of tools
- insufficient training

This also includes downtimes which are caused by shortcomings in plant operation, or ensuring the process.

The preventive maintenance time - T_W includes any work to be done according to the maintenance schedule:

- scheduled servicing
- routine maintenance
- test runs following preventive maintenance

This guideline also contains a form for recording downtimes.

2.5.2. AMT - Production Equipment Availability - A Measurement Guideline

This guideline defines all the times in which the components of the production systems can be found, according to Figure 1, [14]:

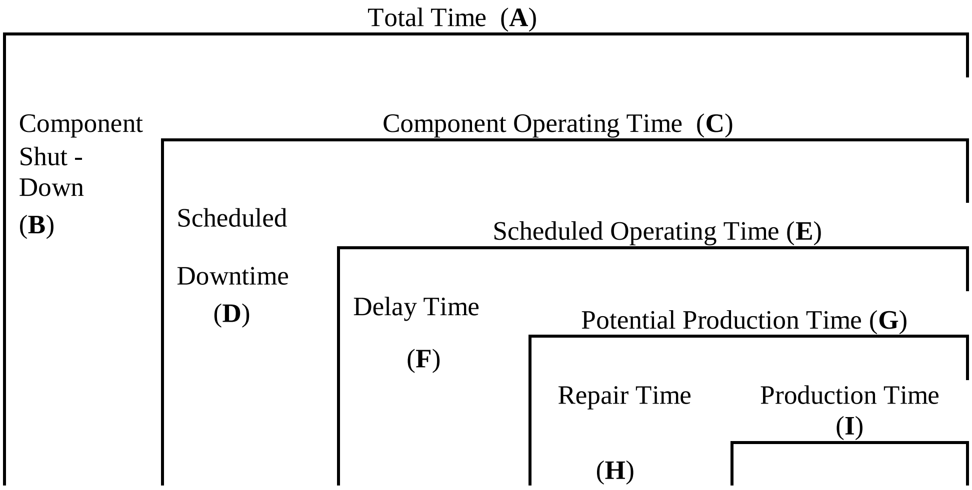


Fig. 1 Component Availability Parameters

Component availability is defined as the percentage of potential production time (G) during which equipment is operable, that is, operations are not prevented by component malfunction (or process difficulties in turnkey systems) [14]:

$$EquipmentAvailability = \frac{ProductionTime(I)}{PotentialTime(G)} \times 100\% \tag{23}$$

This guideline also introduces the term "overall availability". According toEq.24:

$$OverallAvailability = \frac{ProductionTime(I)}{ScheduledOperatingTime(E)} \times 100\% \tag{24}$$

3. COMPONENT AVAILABILITY MANAGEMENT IN CONSTRUCTION PROJECTS

Managing the availability of components / machines in construction projects involves:

- defining and classifying the availability function
- establishing a database of the availability of components from previous work (operational availability – A_o)
- predicting the project availability (A_p) of components
- determining the current availability of components at the end of the project and business year
- analysis of current and projected values
- updating the database with new values of current (operational) availability

3.1. Defining and classifying equipment availability

The availability of a construction machine or plant is the probability that will perform the function at a random time t, that is, at a given time t of the interval [0 - T].

The basic equation of availability according to Eq. 25 is:

$$A = \frac{OperationalTime + StandbayTime}{OperationalTime + StandbayTime + DownTime} \tag{25}$$

The component may be available, but without a function due to the failure of other parts of the system. Specifically, the component can be found in the following states:

- operational time with maximum capacity
- operational time with reduced capacity
- stand-by time (component is available with zero capacity)
- down time (component is in the state of outage or under scheduled or unscheduled maintenance)

This means that Eq. 19 needs to be modified to differentiate the time in which the component has the capacity of zero. Namely, the times "h_i" belong to the different capacities of the components (zero, reduced and maximum) in the case of an available component. The times "h_j" belong to the capacities of the zero value when the component is not available. So, the term for the production availability of a component of construction production systems can be adopted according to the Eq. 26:

$$A_{ocurrent} = \frac{\sum_{i=1}^{n_o} h_i \times n_i}{\sum_{i=1}^{n_o} h_i \times n_i + \sum_{j=1}^{n_f} h_j} \tag{26}$$

Where:

n_o – the times in which the component is available with different capacities

n_f – the times in which the component is unavailable

This approach to defining availability provides a realistic view of the cost of components for all the states in which the component can be found.

Equation 26 is the consequence of the expansion of Eq. 15 for the operational availability of a component from a cost perspective. By observing the time in which the component functioned and ignoring the oscillations in capacities, it follows that:

$$A = \frac{OT + ST}{OT + ST + TCM + TPM + ALDT} = \frac{\sum_{i=1}^{n_o} h_i \times n_i}{\sum_{i=1}^{n_o} h_i + \sum_{j=1}^{n_f} h_j} \tag{27}$$

3.2. Assessment of equipment availability

The first estimates of availability in the field of technical systems were based on the determination of statistical distributions for failure time and repair time [3]. Due to the long enough time in which the production systems function, probability distributions reach a statistical equilibrium, which means that production processes are in a steady state [8], [9]. The availability of components in such cases would be estimated on the basis of Equation 10, while the given time in the equation can be determined by the frequency balancing method.

Taking into account the life cycle of the components (LC), three characteristic periods are observed in which these components function. In fact, the life cycle of the components consists of early, constant, and late failure rates (λ). Each construction system consists of components with different stages in the life cycle which is non-homogeneous in terms of the age of the components. This feature of the components and systems leads to the modification of the frequency balancing method so as to increase the accuracy of component availability estimates. The results obtained did not differ significantly from the application of the frequency balancing method and the Monte Carlo simulation method [1], [2]. Specifically, when there are data on availability from the previous work (operational availability), then the availability estimates for periods *I*, II and III can be made on the basis of Eq. 28, 29 and 30 [1], [2].

Equation 27 is used to estimate the project operational availability of components (A_{poI}) from period I [1], [2]:

$$A\,po_I = (A_{o,aritmetic \cdot mean} + A_{o,\max})/2 \tag{28}$$

Equation 28 is used to estimate the project operational availability of components from the middle part of the life cycle (period II) [1], [2]:

$$A\,po_{II} = max\left| A_{o,\,aritmetic \cdot mean},\, A_{o,\,last \cdot year} \right| \tag{29}$$

Equation 29 is used to estimate the project operational availability of components from the last part of the life cycle (period III) [1], [2]:

$$A\,po_{III} = A_{o,\,last \cdot year} \tag{30}$$

3.3. Algorithm / procedure for equipment availability management

The management of the availability of components / machines (C_{ij}) of construction production systems is shown in Fig. 2. For "i" and "j" the following applies:

$$i = 1,2,...,\, n \tag{31}$$

$$j = I,\, II,\, III \tag{32}$$

Where:
n – number of system components
I, II, III – life cycle periods of components
A_{oij} – operational availabilities from data base according to Eq. 26
A_{poj} – estimated component operational availability according to Eq. 28, 29, 30
$A_{ocurrent}$ – current component operational availability (availability after project completion) according to Eq. 26:

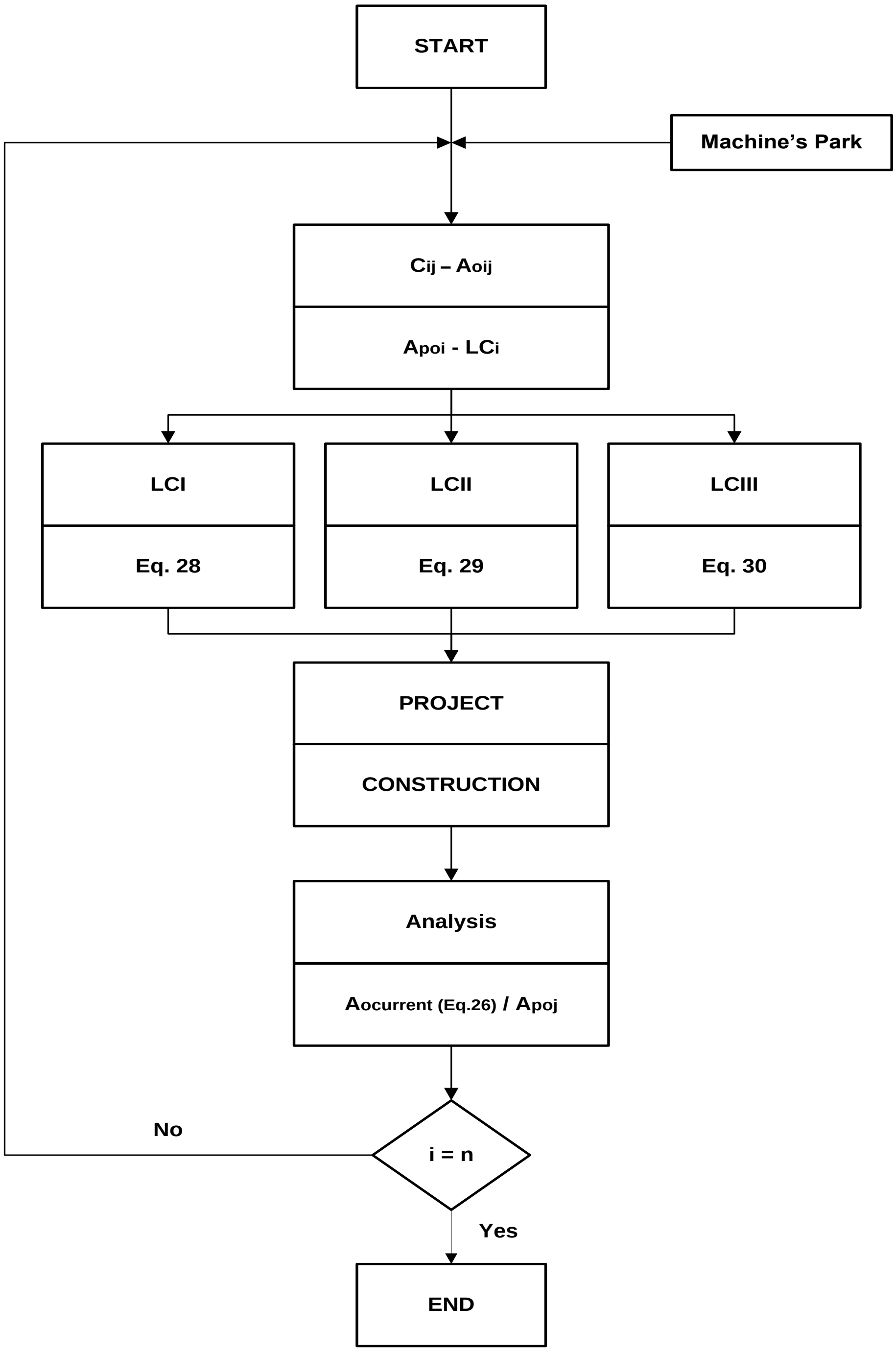


Fig. 2 Algorithm / procedure for equipment availability management

4. ILLUSTRATIVE EXAMPLE

In this section, the component production availability discussed above is illustrated with an example from the data base of an asphalt plant from a road construction company (Vojvodinaput-Zrenjanin).

The asphalt plant has a maximum capacity of 100 tons per hour (t/h) and has produced 92,780.00 tons of bitumen bounded materials for a period of 1077 hours. The planned hours of work with the nominal capacity were 92,780.00 / 90 = 1031 hours. In the period of question, according to Eq. 26, the plant was under the following conditions:

- maximum capacity Q_{max} = 100 t/h, h_1 = 180
- nominal capacity Q_{nom} = 90 t/h, h_2 = 370
- reduced capacity Q_{red} = 85 t/h, h_3 = 488
- stand by Q_{stb} = 0 t/h, h_4 = 22
- state of outage Q_{out} = 0 t/h, h_5 = 17

Capacity as a function of time for component availability is illustrated in Fig. 3.

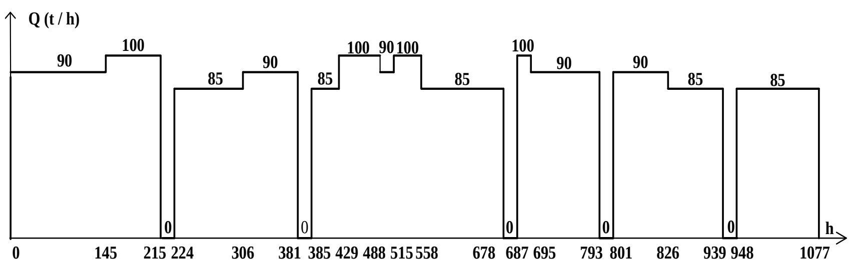
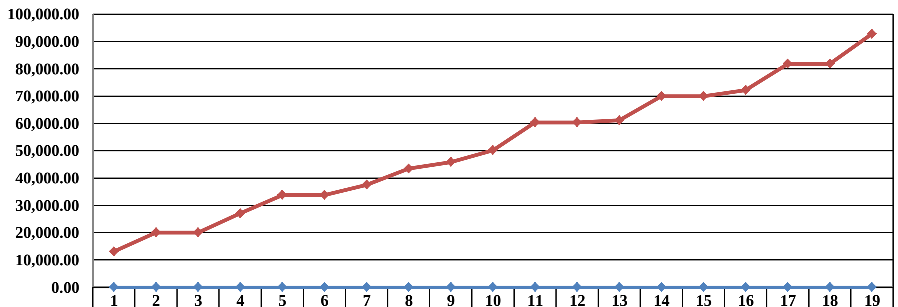


Fig. 3 Ratio between capacity and time as a function of plant availability

Figure 4 shows the planned amount of work (Q) and events (E) related to oscillations in capacities during the project.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Qi	13050	20050	20050	27020	33770	33770	37510	43410	45840	50140	60340	60340	61140	69960	69960	72210	81815	81815	92780
E	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19

Fig. 4 Planned quantity of work as a function of capacity variation

According to equation 26, the production availability of the component is:

$$A_{ocurrent} = 1031/1077 = 0.9573$$

According to equation 29, the estimated production availability of the component is (see appendix):

$$A_{poj(II)} = 0.9555$$

The difference between the current and estimated availability is:

$$A_{ocurrent} / A_{poj(II)} = 0.9583/0.9555=1.0029, \text{ i.e., } 0.29\ \%$$

5. Discussion and Conclusion

The choice of the appropriate equation for the production availability of construction system components is influenced by oscillations in the capacities that are constantly presented in practice. Also, the separation of the time when the component is in a stand-by and a failure, i.e. at times when it is available and does not perform the function (ST) and the time when it is in failure (MDT). This approach is justified by the different costs that belong to the specified times and obtaining real data on the operational availability of the components / machines. Operational availabilities are the part of a database on the behaviour of components from the previous work.

Using the classic approach to defining the availability according to Eq.20 and not respecting the oscillations in capacities and availabilities when the component does not perform its function, the availability value is:

$$A = (1077\text{-}22\text{-}17)/1077= 0.9638$$

This approach creates a misconception about the behaviour of the component and increases the risks in the cost estimation in the bidding phase.

Also, by applying Eq.15, which recognizes the availability when the component does not perform the function (ST), but does not respect time with different capacities, it may consequently have the above mentioned omissions. Namely:

$$A_o = (1077\text{-}22)/1077=0.9796$$

We believe that the equation proposed in this work for determining the operational availability of production components in project-organized (construction) systems (Eq. 26) is both appropriate and effective In fact, the test result obtained, which varies by 0.29% in relation to the estimated value, i.e. 2.9 ‰, confirms the feasibility of using an equation and assessment methodology based on the non-homogeneity of construction systems in terms of the different life cycles of the components.

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APPENDIX

Table A.1 shows the operational availabilities with elementary statistics of the tested component/asphalt plant from the data base of the company for road construction-Vojvodinaput-Zrenjanin.

Table A.1 Operational availabilities of the asphalt plant during the research period

Component	Asphalt Plant W - 100				
Year / Parameter	MTBF	MTTR	λ	μ	A_o
2005	92.80	4.00	0.0108	0.2500	0.9587
2006	102.77	4.46	0.0097	0.2241	0.9584
2007	96.56	4.78	0.0103	0.2093	0.9531
2008	118.67	5.33	0.0084	0.1875	0.9570
2009	126.50	6.33	0.0079	0.1579	0.9523
2010	138.80	6.40	0.0076	0.1563	*0.9534*
Minimum	92.80	4.00	0.0076	0.1563	0.9523
Maximum	138.80	6.40	0.0108	0.2500	0.9587
Variation interval	46.00	2.40	0.0032	0.0937	0.0064
Arithmetic mean	112.68	5.22	0.0091	0.1975	***0.9555***
Mid interval	115.80	5.20	0.0092	0.2032	0.9555
Deviation from the right	135.68	6.42	0.0107	0.2444	0.9587
Deviation from the left	89.68	4.02	0.0075	0.1507	0.9523

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KLASIFIKACIJA RASPOLOŽIVOSTI SA ASPEKTA PRIMENE NA GRAĐEVINSKE PROIZVODNE SISTEME: PREGLED

Cilj rada je unapređenje postojećih klasifikacija raspoloživosti komponenata sa aspekta primene na građevinske sisteme. Građevinski proizvodni sistemi pripadaju projektno organizovanim sistemima sa serijsko paralelnom strukturom, sa ili bez redundantnih komponenata i funkcija raspoloživosti ima značajan uticaj na pokazatelje performansi komponenata i sistema. Glavni pokazatelji funkcionisanja komponenata su raspoloživost, kapacitet, troškovi i projektno vreme. Novi pristup klasifikaciji omogućuje izbor odgovarajućeg pristupa proceni projektne raspoloživosti i upravljanju mašinskim parkom kompanija. Novi pristup je testiran na primeru iz prakse. Dobijeni rezultati potvrdili su opravdanost za proširenje klasičnog pristupa klasifikaciji proizvodne raspoloživosti komponenata.

Ključne reči: *raspoloživost, građevinska komponenta, indikatori komponenata, proizvodni system*