**Practical Software and Systems Measurement Continuous Iterative Development**

**Measurement Framework**

**Part 2: Measurement Specifications: Cumulative Flow**

Version 2.1

April 15, 2021

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| **Developed and Published by Members of:** | | |
| Practical Software & Systems Measurement | National Defense Industrial Association | International Council on Systems Engineering |
|  | NDIA 100 Year logo |  |
| Product No.  PSM-2021-03-001 |  | Product No.  INCOSE-TP-2020-001-06 |

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PSM Product Number: PSM-2020-06-001

INCOSE Product Number: INCOSE-TP-2020-001-06

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# Measurement Specifications

## Cumulative Flow (Team, Product, or Enterprise Measure)

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| **Measure Introduction** | |
| **Description** | Cumulative flow is a tool to visualize work in progress, cycle time and throughput. In this specification, the indicator (Cumulative Flow Diagram) is described, with base and derived measures that duplicate other measures listed above.  Continuous iterative development (CID) methods are focused on the delivery of capabilities/features achieved by managing the flow and throughput of work through a process. Understanding and managing flow is fundamental to achieving stable processes with predictable performance and the efficient use of resources.    Flow is visualized and represented graphically in a Cumulative Flow Diagram (CFD) depicting the total quantity and transition of work items in each workflow state over a time period. It is generally desirable that the amount of work distributed across each process workflow state is in balance (new work is equivalent to the completion of work in each workflow state). This can be visualized on a CFD as roughly parallel upper and lower bounds of the cumulative work through each state. Failure to match departures and arrivals for each state can result in queues, backlogs, or inefficiencies in the progress of work completion or utilization of resources.  Adherence to effective processes ensuring standard CFD assumptions, rules, and constraints, can help teams achieve predictable performance.  Reference: Actionable Agile Metrics for Predictability (Vacanti, 2015) |
| **Relevant Terminology** | |  |  | | --- | --- | | Cumulative Flow Diagram | A tool used in queuing theory showing whether the flow of work is consistent; visually points out shortages and bottlenecks. | | Throughput | The number of work items completed per unit time. | | Work in Progress (WIP) | The number of work units in progress between workflow steps in a process. | | Work Items | Item that indicates the type of work and what needs to be done (e.g., tasks, stories, features, capabilities). It may include the target date for completion. | |

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| **Information Need and Measure Description** | |
| **Information Need** | Is the flow of work moving forward through the value stream (through the process workflow states)?  Is the throughput of work predictable?  Are there queues or delays in our process workflows that prevent us from optimizing throughput? |
| **Base Measure 1..N** | Base Measures 1-N: The number of work items in each of N workflow states. Collected using counts or times.  Note: These states vary by project, organization, or defined process. For the example indicators below, the workflow states used include:   * To Do: Work items from the product backlog that have been approved/accepted for implementation (committed to), but not yet started. They generally have been assigned to an iteration or release. The product backlog may also include items that are never implemented. To best depict flow, CFDs do not typically include Backlog work items. * In Progress: Work items that have been approved/accepted for implementation (committed to) and have started development. * Done: Work items have completed all development activities in an iteration and are ready for internal release. * Deployed: Work items have completed all development activities defined by the process, including integration and test activities, and are deployed in an internal or external release. |
| **Derived Measure 1** | Approximate Average Cycle Time = average duration for all completed work items  Note: The duration is an approximate based on the set of completed work items for a given time range. It is not based on an average of individual work item durations. See Cycle Time / Lead Time specification for a measure based on individual work item durations.   * Other derived measures for transitions between workflow states can be calculated similarly. |
| **Derived Measure 2** | Throughput = average of Work Items Done per unit time |
| **Derived Measure 3** | Work in Progress = average of Work Items in Progress per unit time |

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| **Indicator Specification** | |
| **Indicator Description and Sample** | Flow is commonly depicted in a Cumulative Flow Diagram (CFD),Figure 1, depicting the stacked cumulative quantity of process arrivals, departures, and WIP in bands for process workflow states over time, as illustrated in the example below. The amplitude of the CFD chart indicates the amount of work in each workflow state.    Figure 1: Cumulative Flow Diagram  This example CFD indicates a project workflow with a team capacity that is well balanced with demand. The number of tasks in each workflow state (height of the bands, or vertical distance between lines) is holding fairly steady and narrow, with relatively parallel lines (slopes) indicating a balance of work arrivals (added to the top teal, To Do, Band) transitioning smoothly into subsequent workflow states culminating in the bottom dark blue, Deployed, band. There are no notable queues, delays, or backlogs (widening CFD bands), except for the arrival of new needs and objectives from the customer in September and March. These are reflected in the Release Backlog (increases in the height of the teal To Do band). These were steadily worked off and implemented by the project team at its consistent rate and capacity (indicated by maintaining fairly stable slopes of the In Progress, Done, and Deployed lines). Throughput rate is steady with no significant changes, except for a short flattening of the progress curves over the December holiday period, that resumed quickly when the team returned to full staffing in January.  This workflow balance over the year shown is substantiated further by an average task departure rate (1.31 tasks/day), well matched to demand reflected in the average arrival rate (1.29 tasks/day). |
| **Indicator Description and Sample (cont.)** | For projects adhering to standards for collection and reporting of CFD data, derived measures for average WIP, average Throughput, and approximate average Cycle Time are related by Little’s Law (as discussed in *Actionable Agile Metrics for Predictability*). Generally, these summary cumulative measures can be derived and visualized for a given time range from a CFD diagram as in the abstraction shown in Figure 2. The figure below further illustrates these relationships.      Figure 2: Notional CFD Diagram  Continuing from the above project CFD example, the project average WIP, average Throughput, and approximate average Cycle Time can be calculated and plotted over time, as in Figure 3.    Figure 3: Workflow by Period and Rolling Average  This example provides further numeric substantiation of process effectiveness consistent with the CFD indicator analysis. Derived CFD measures for average WIP, average throughput, and average cycle time indicate fairly stable performance over time that could be useful in predictably planning future estimates. Approximate Lead Time (turnaround for implementing and deploying accepted customer requests) has reduced on average over the last year, even considering the two significant spikes in receipt of new requests and the short delays in throughput over the December holidays.  Note that although CFD measures may indicate stable and consistent workflow process performance, this does not necessarily imply this level of performance fulfills the business need. Process improvements and performance efficiencies may yet be needed to meet the Voice of the Customer. Also note these measures may be specific to the team (e.g., methods for defining tasks, stories, story points) or application domain (e.g., embedded firmware, command and control, information systems, high reliability space applications), so organizations should be cautious about projecting performance across other projects. It may be most beneficial to monitor overall workflow trends and potential areas of concern rather than focusing on absolute measures. |
| **Analysis**  **Model** | Is work arriving and being completed at consistent rates? Is there a steady proportionate ratio of WIP across workflow states, or are there queues, delays or inefficiencies indicated by widening CFD bands that should be addressed?  The shapes of CFD bands indicate if the flow of work is being processed and completed at predictable steady rates (e.g., consistent slopes with relatively parallel bands). Other shapes (e.g., diverging bands, flat lines, S-curves) can indicate inefficiencies, mismatched arrivals and departures, or delays in completing the flow of work.  Is cycle time and throughput compatible with achieving the project plan and product roadmap? Are these measures stable? Comparing derived average cycle time against actual calculations (see Cycle Time/Lead Time specification) can indicate potential process anomalies, such as giving preferential priority to certain tasks. What can be done to increase throughput or reduce WIP, if necessary, to meet performance objectives?  Additional details of CFD derived measures and related topics such as technical debt are beyond the scope of this specification and are described further in referenced materials. |
| **Decision Criteria** | Significant variations (e.g., + 10%) in the slope or width of CFD workflow band curves may indicate performance issues, queues or delays in bringing work to closure. Root causes should be analyzed, and corrective actions implemented as appropriate to bring workflow back within expected ranges needed to execute the plan. |

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| **Additional Information** | |
| **Additional Analysis Guidance** | Anomalous CFD band shapes indicating potential delays or negative trends in WIP, cycle time, or throughput may require analysis of root causes. Often reducing WIP or batch sizes can improve process throughput and stability. |
| **Implementation Considerations** | CFDs are often available as built-in reports from common agile workflow management tools, which provide additional filtering and reporting options according to the process workflow states in use. CFDs can also be constructed based on measures collected, analyzed and reported using spreadsheet tools. The sample intervals for collection or analysis of CFD data items (e.g., daily, weekly, monthly) may vary based on the program’s defined processes or business environment. |

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| **Additional Specification Information** | |
| **Information Category** | 1. Schedule and Progress 2. Process Performance |
| **Measurable Concept** | 1. Work Unit Progress 2. Process Effectiveness |
| **Relevant Entities** | Tasks, stories, features, capabilities. |
| **Attributes** | Arrivals / departures for workflow state transitions |
| **Data Collection Procedure** | Workflow state information (quantities by state over time) and Cumulative Flow Diagrams are typically obtainable directly from software task planning and management tools. |
| **Data Analysis Procedure** | Cumulative flow is analyzed by the team regularly (e.g., daily or weekly) to monitor work in progress and completion. Measures are analyzed periodically (e.g., monthly, quarterly, end of each iteration or release) to determine if process performance levels are in line with objectives and sufficient to meet work remaining in the project plan. Corrective actions and process improvements are identified to bring performance within expectations as needed. |