The Need to Reconcile Concepts that Characterize Systems Withstanding Threats

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Abstract
Desirable system performance in the face of threats and disruptions has been characterized by various management concepts. Through semi-structured interviews with editors of journals in the fields of emergency response and systems management, a literature review, and professional judgment, we identified nine related and often interchangeably-used system performance concepts: adaptability, agility, reliability, resilience, resistance, robustness, safety, security, and sustainability. We analysed expert responses and reviewed the linguistic definitions and mathematical framing of these concepts to understand their applications. We found a lack of consensus on their usage between interview subjects, but using a mathematical framing enriched the linguistic definitions and enabled formulating comparative visualizations and system-specific definitions for the concepts. We propose a conceptual framing to relate the concepts for management purposes. A better understanding of these concepts will allow system planners to pursue management strategies best suited to their unique system dynamics and specific objectives of “goodness” that all these concepts bring.

Introduction
Today’s natural and human-built world constitute a complex and interconnected system. System performance affected by inevitable disruptions can be expressed through many concepts, including adaptability, agility, reliability, resilience, resistance, robustness, safety, security, and sustainability. The universal objective of “good” performance has produced ambiguity over the various means for achieving it. The Federal Emergency Management Agency (FEMA) supports community resilience in the face of disasters, and the Center for Disease Control studies bacterial resistance to antibiotics. Organizations benefit from agility, and the US military seeks to foster robustness, security, and resilience. The US Federal Motor Carrier Safety Administration prevents commercial motor vehicle-related fatalities and injuries. National parks should be sustainable, while critical infrastructure and cyberspace demand security, the City of Boston is developing its resilience and adaptability, and electricity grids value reliability.

There is no consensus across fields regarding the meaning of disruption-related terms nor the relationships between them. The field is plagued with examples numerous conflicting definitions and misuse for each one of 9 concepts listed above. A review (SI 1) reveals that there are many papers comparing individual concepts to each other, but there is no comprehensive evaluation of all of them in relation to the overall system performance.
The concepts themselves are not always consistently defined or evaluated. Taking resilience as one example, several review papers find multiple and often competing definitions of resilience (e.g., Wied et al. 2019, Hosseini et al 2016, Southwick et al. 2014). In examining recent Risk Analysis publications, Specking et al. (2019) relate resilience to “utilities” like reliability, availability, maintainability, that help the system achieve performance through accomplishing its designed tasks. Yonson and Noy (2019) quantify resilience as the ability to minimize losses following a disaster and its consequent asset losses, and also by the ability to reconstruct and recover quickly. Gillespie-Marthaler (2019) define sustainable resilience as maintaining desired system performance while considering intrasystem and intergenerational distribution of capital or consequent vulnerabilities. Yu and Baroud (2019) measure community resilience by the rate of recovery, which can be predicted according Bayesian analyses of past recoveries. Beyond Risk Analysis, Donahue et al. (2016) found characterizations of resilience using resistance and robustness and sustainability. Creaco et al. (2013) found resilience to be part of an indirect measure of reliability. Marchese et al. (2017) identified three frameworks relating resilience and sustainability: those that claimed resilience was a component of sustainability, those claiming sustainability was a component of resilience, and those claiming the concepts are unrelated.

The frequent and inconsistent usages of the terms risk mischaracterizing system management objectives. For managers seeking to improve a system’s ability to continue functioning through disruptions, the system performance expectations and available strategies for supporting it should be clearly differentiated. As human-managed systems increasingly support various societal activities, funding allocations should reflect the strengths, weaknesses, and opportunities embodied in various system characteristics, which becomes difficult when the interpretations of these concepts vary between disciplines. To avoid redundant, counterproductive, or unnecessarily costly efforts, terms for system responses to threats require clear distinctions.

To examine the magnitude of disconnect in the field, we elicited observations from editors of top journals in the field relevant to risks, disasters, safety and found that the interpretation of the nine concepts differs widely across the very people who define this field. We then examine the terms’ definitions, etymologies to find linguistic origins and identified areas of clear differentiation, but multiple overlaps as well. Finally we reviewed literature to find examples of first principle mathematical framing of these concepts to further substantiate differentiations. We conclude with a proposed conceptual mapping that synthesizes the differences and relationships that we identified and can support communication between strategic system planners of different fields and facilitate transferring successful management strategies. To our knowledge, such an overarching analysis has not been previously provided.

**Synthesizing Expert Views on Thematic Concepts of System affected by Threat**

We conducted semi-structured interviews with eleven experts from systems management fields. We identified ten journals using Web of Science to search multiple terms relevant to systems management, risk, disasters, safety, and other relevant concepts. Ten editors were contacted, and through soliciting additional names from the editors who responded, we created a purposeful sample that yielded 11 interview responses, including nine editors of academic journals (impact factor > 1 or their designees and two NSF program directors.
For the interviews, we hypothesized that certain characteristics about the type of disruption encountered and the system’s reaction to it is implied in the use of terms in different fields. Thematic discourse analysis help to classify each term according to three dichotomies:

1) Chronic vs. acute threats or disruptions
2) Focused vs. broad system response
3) Internal vs. external system response

Chronic threats are ordinary, repetitive, and expected over the planning horizon, whereas acute threats are rare, extreme, and perhaps unexpected events that may or may not occur during the planning horizon. The boundary between chronic and acute threats can change over time, such as the case of flooding risks under climate change. Next, a focused system response is capable of absorbing a specific type of threat, while a broad response addresses many potential threats, potentially including new or unknown threats. Finally, we asked whether the system’s threats are absorbed externally, by a shield, or internally, by dedicated system component (e.g., a human immune system). The informal discussions also solicited additional concepts for our list.

Table 1 includes a summary of integrated interview responses. Detailed results and explanations of the analysis are presented in SI2. Cells marked with X show the experts’ most common response (colored green) to the question of which aspect of a dichotomy best characterizes each term. The color saturation difference between red and green indicates the strength of the responses towards one aspect of the dichotomy across the experts. Responses that were tied (no coherency) are shown in yellow.

Table 1. Results of Semi-Structured Interviews

| Threat Type | Acute | Chronic | Focused | Broad | External | Internal |
|-------------|-------|---------|---------|-------|----------|----------|
| Adaptability|       | X       |         | X     |          | X        |
| Agility     | X     |         |         |       |          | X        |
| Reliability |       | X       |         |       |          | X        |
| Resilience  | X     |         |         | X     |          | X        |
| Resistance  | X     |         |         |       | X        |          |
| Robustness  | X     |         |         |       | X        |          |
| Safety      |       |         |         | X     |          | X        |
| Security    | X     |         |         |       |          | X        |
| Sustainability|     | X       |         |       |          | X        |

The results of the semi-structured interviews show little consensus. However, respondent affirmation is consistent around two concepts: systems characterized by sustainability were viewed almost unanimously to be coping with chronic threats, and adaptable responses were mostly considered to be broad defenses. Safety and security received the same categorizations in all three dichotomies, as did resistance and robustness, though they differed within individual interviews. Many experts found the proposed dichotomies irrelevant to differentiate between the terms, sometimes granting all terms the same score in a given dichotomy. One expert theorized that he might evaluate the dichotomies differently were he asked a second time since they were so tenuously related to his idea of the
concepts. Expert suggestions for additional dichotomies included long-term/short-term and rote vs.
creative responses.

These results indicate that a basis for clear differentiation between the concepts will not be conclusively
found within the usages of current scholarship, and reflects a general lack of coherence seen in the
literature. The National Science Foundation has dedicated considerable effort to defining these terms
already without a clear consensus. As buzzwords like resilience and sustainability emerge in response to
new realities and challenges, some confusion and interpretation should be expected. These terms are
active in English vernacular and can be deployed to systems analysis for a variety of reasons that may
deviate from an accurate reflection of the term’s actual meaning. In gerontology, for example, models
for resilience in aging arose from critiques of the existing model of successful aging (Cosco 2018), and
the resilience application introduced therein does not greatly resemble resilience applications used
elsewhere, such as the National Academy of Science definition for resilience to natural disasters (Klasa
et al. 2020, forthcoming). It happens that when a field begins using a term, its usage reflects hysteresis
in the field’s existing terminology and the need for innovation rather than a close match with a term’s
actual meaning in other contexts. Thus, as more fields use more terms, overarching terminology
meanings can become increasingly muddled.

Reconciling the usage of these terms and their relationships to each other might require some fields to
relinquish their current terminological frameworks, which would not be defensible without a firm basis
in existing consensus usages. This does not, however, diminish the importance of ease communication
and solidify the concepts in their applications everywhere, but it does emphasize the difficulty of the
task. There is a lost opportunity for efficiency and learning, and an increased chance of
misunderstanding in communications between scientists, funders, and decision makers. Thus our
analysis now turns to other sources of information: linguistic definitions followed by mathematic
framings.

Critical Examination of Linguistic Characteristics

Our linguistic exploration used two readily available sources the online Oxford Lexico Dictionary
(lexico.com) and the Online Etymology Dictionary (etymonline.com). For consistency, we used the first
noun definition provided for all the terms with the exceptions of robustness and resistance, which use
the dictionary’s demarcated system-specific definitions. Next, we listed relevant adjectives and verbal
permutations of each term. The etymologies consider the roots of each concept and their origin
meanings, including splitting the word into its components where applicable (Table 2). Finally, the last
column lists the outcome of our interpretation of the definitions, grammar usages, and etymologies,
summarized in the text following Table 2, and provided in full in SI2.

| Noun     | Oxford Definition                  | Adjective | Verb | Etymology                      | Interpretation |
|----------|-----------------------------------|-----------|------|--------------------------------|----------------|
| Adaptability | The quality of being able to adjust to new conditions. | Adaptable | Adapt | VERB Latin: \( ad + aptare \) to[make] + to fit | Reaction       |
| Agility   | Ability to move quickly and easily. | Agile     |      | ADJECTIVE Latin: \( agilis \) nimble, quick | Action         |
The noun definitions contain elements providing mutual exclusivity, with the possible exception of resistance and robustness. Some terms characterize actions without reference to stimulus (agility), while others reference a change or discontinuity in conditions that necessitate reactions or responses on the part of the system (resistance, robustness, resilience, adaptability). Sustainability and reliability refer to overall performance, and safety and security are defined as a state or condition, which can be synonyms. These categorizations do not correspond to the qualifiers in the definitions (quality, ability, capacity) except in the case of safety and security.

Five etymologies stem from verbs, and the remaining four from adjectives (security, safety, agility, and robustness). All exist as adjectives and nouns in modern form. From this, we conclude that it is easier to characterize a concept (verb becoming an adjective) than to describe what it does (adjective becoming verb). We examined the six verbal forms of the concepts within sentence structure and found that three (adapt, resile, resist) modify subjects while three (rely, secure, sustain) modify objects. This suggests more direct actionable control over the concepts of adaptation, resilience, and resistance, and less direct control over reliability, security, and sustainability.

According to the Online Etymology Dictionary, all nine terms stem from Latin roots, with some further traceable to Proto-Indo-European origins. Thus, the terms have existed simultaneously for millennia. There is the notable repetition of the prefix “re” in resistance, resilience, and reliability, from the same Latin root meaning again, which is closely associated with the word against. The remaining prefixes include a verb, making adaptability highly action-oriented, contrasted with an adjective modifying a noun (se + cura), and preposition modifying a verb (sub + tenere), both of which denote more steady state. Thus the prefixes suggest actions (adaptability), reactions (reliability, resilience, resistance) and more steady states (security, sustainability).
Finally, the noun forms of the concepts take particular suffixes, \(-ability\), \(-ance/-ence\), \(-ity\) and \(-ty\). We note that the suffixes do not directly correspond with the assignments of quality/capacity/ability/state/condition provided by the definitions. Suffixes affect a noun’s meaning. The nouns \textit{sustenance} and \textit{reliance} are markedly different concepts from \textit{sustainability} and \textit{reliability}. The \(-ance\) suffixes may denote an earned or acquired resource that can be reliably deployed (see intelligence vs. intelligibility); thus \textit{resilience} and \textit{resistance} may denote some permanence in characterization or assurance of action. This is contrasted with \(-ability\) suffixes that refer more to nebulous future potential or uncertain characterization. The \(\text{“-ity and -ty”}\) suffixes imply a state (see immunity vs. immunization, or indignity vs. indignation), indicating more certainty in characteristic.

The grammar, prefix, and suffix characterizations do not perfectly align with our interpretations of the modern definitions, but there is sufficient overlap (see Table is SI3) to suggest that modern definitions capture the variability between these different linguistic analyses. Thus, we assert that the vernacular division of action, reaction, state/condition, and overall performance are the most informative interpretation of the different concepts.

**Mathematical Framing**

The linguistic presentations of the concepts suggest that they can be evaluated and measured for natural phenomena and systems operations. But while heuristic metrics based on checklists and the like abound, definitions from first principles are somewhat rare in the scientific literature. Where such definitions are found, they tend to reside in a discipline for which the concept is essential, often to the exclusion of other disciplines. In identifying and examining such scientific formulations, we found that these mathematical framings substantiate the vernacular for the concepts. We approach this analysis systemically: these quantitative definitions can provide a foundation for differentiating the terms according to particular system characteristics. Though our searches were not comprehensive, the results show consonance and provide insight to the specific contributions of each concept within a systemic context. Table 3 presents abstracted versions of the definitions and categorical interpretation which relate to general systems.

The definitions of Table 3 allowed us to populate the other columns. Firstly, the dichotomy of acute vs. chronic was not clearly differentiated because multiple acute threats could occur, and for some concepts, like reliability or sustainability, the terms did not necessarily imply an outside threat so much as inherent internal variation or degradation, for reasons unknown. Therefore, we found that two categories of disruption type existed: external acute/chronic, and unspecified-source chronic. We also found that the terms characterized different periods within the course of disruptive events. Some corresponded to the disruption’s impact on the system’s performance, whereas others characterized the system’s response after the worst of the damage has occurred, or both. Next we propose an equation, parsed into a numerator and a denominator. The denominators that use “event” could certainly be averaged, summed, or otherwise combined over time, but also stand on their own, while the terms with time as the denominator cannot be adequately characterized for a single disruption event.
| Concept       | Mathematical Framing                                                                 | External Threat       | Failure/Recovery  | Proposed Equation                                                                 |
|--------------|--------------------------------------------------------------------------------------|-----------------------|-------------------|-----------------------------------------------------------------------------------|
| Adaptability | The probability that a population will ultimately be able to achieve a given level of fitness after an environmental disruption, e.g., a population with limited genetic variability will not be able to adapt (even after the initial die-off) as much as one that has more variability (Stewart et al. 2012). This has been generalized to the ability of biosystems to recover functionality (Ch'ng, 2007). | External acute or chronic | Both              | Population * Probability of (necessary-to-survive) individual change (Per) Event |
| Agility      | The ability to execute rapid whole body movement with change of velocity or direction in response to a stimulus (Sheppard and Young, 2006).                                                                 | External acute or chronic | N/A               | Response time/Response time needed to avoid penalty (Per) Event                    |
| Reliability  | The percentage of time that a system function remains within a threshold of acceptable performance. For voltage, some variation is unavoidable but too much variation causes problems. In systems engineering, reliability may be associated with a probability of failure over a given time period under typical operating conditions. Any quantitative measure of reliability depends on both the variability of the system and the tightness of its thresholds. | Chronic/ internal     | Both              | Values within thresholds/ values outside thresholds (Over) Time                   |
| Resilience   | A perfectly resilient rubber ball is one that bounces back to the same height it is dropped from. A softer rubber ball may return to its original shape less quickly, dissipating energy through the process, and subsequently bounce to a lower height with less potential energy. Thus, resilience in the ball preserves energy through quick and full recovery. | External acute or chronic | Recovery          | Percent critical function recovery/recovery time (Per) Event                      |
| Resistance   | The ratio of electric pressure (Volts) to the amount of current (Amps). Resistance characterizes the system’s ability to absorb pressure while minimizing the impact on the system. | External acute or chronic | Failure           | Pressure/damage to system (Per) Event                                             |
| Robustness   | The amount of pressure the system can withstand without any change in functionality. This appears in various types of engineering: “Robustness is the ability of the system to avoid failure modes, even in the presence of realistic noises” (Clausing 2004) or “the ability of a system to resist change without adapting its initial stable configuration” (Wieland and Wallenburg, 2012). | External acute or chronic | Failure           | Pressure (at which system fails) n/a                                               |
| Safety       | [Not a mathematical concept in any scientific or engineering area we have identified]. Road safety is a product of collision probability and severity. Low values for either produce higher levels of safety on the roads. (Sayed et al, 2010). | Chronic/ internal     | Failure           | Probability of failing * consequence of failure (lower values are better) (Over) Time |
| Security     | The resources hackers needed to overcome system protections. For instance, a 128 bit encryption key can be penetrated by a hacker with the resources to try $2^{128}$ passwords (Goldreich 2005). | External acute or chronic | Failure           | Pressure (at which protection fails) n/a                                            |
| Sustainability | The continuous compensation of irreversible entropy production in an open system (Robinett et al. 2006). That is, the more sustainable a system, the less outside investment it requires to avoid degradation of functionality under normal operation. | Chronic/ internal     | Both/neither      | Investment (lower values are better) (Over) Time                                  |
Proposed Definitions and Visualizations

With the more concrete meanings obtained through the linguistic and mathematical framings of the concepts, we developed the following definition for the nine concepts:

**Adaptability:** Ability to change internally as necessary to re-establish a high level of fitness after a disruptive event.

**Agility:** Ability to respond quickly to emerging challenges and opportunities.

**Reliability:** Ability to perform within acceptable thresholds.

**Resilience:** Capacity to recover critical functions and adapt following a disruptive event.

**Resistance:** Capacity to absorb disruptions with minimal damage to system functionality.

**Robustness:** Capacity to withstand disruptions without damage to system functionality.

**Safety:** Configuration that exposes to the system to the fewest and least harmful disruptions.

**Security:** Capacity to insulate itself from disruptions that would otherwise interruption functionality.

**Sustainability:** Ability to maintain a high level of functionality without inputs from external resources.

These system-specific definitions can also be visualized in the following nine charts (Figure 1), each showing system performance over time according to greater or weaker manifestations of the different concepts. This visualization demonstrates that there are many different ways to achieve high system performance. Changes may be fast or far-reaching, and constancy may reflect observance of specific thresholds, an ability to withstand disruptions, or an ability to function without auxiliary resources. The concepts are all distinct in their means of approach, but because their objective is the same, these definitions also demonstrate that they are not mutually exclusive, and indeed there are many opportunities to use them in concert. Below we examine each concept in turn and its relationship to the other concepts through its ability to contribute to their realization.
Figure 1. Visualization of Nine concepts considered in the study.
Connecting and Contrasting Concepts that Characterize Systems Withstanding Threats

Using these results, we considered the relationships between the concepts, and how improving one can support another.

High **adaptability** can internal reconfiguration responds directly to the nature of disruptions faced and can lead to improvement to all other terms. It contributes to resilience using its ability to change to better accommodate new circumstances. Adaptability contributes to agility only if the change is fast, thus their relationship is conditional. Adaptability can increase system resistance, robustness, and security are likely to improve according to system needs. All these improvements together ensure a higher level or critical function over time (safety), and the ability to change incorporated in adaptability implies that internal reconfigurations will decrease the need for outside investment and thus improve overall sustainability and consistent functionality of the system (reliability).

**Agility**'s quick responses can contribute to adaptability because adaptability also involves change. High agility can contribute to reliability, which prioritizes the stability that agility allows, and resilience, because high rates of needed change can spur recovery as well as avoid penalty. Agility is distinct from robustness or security, since both entail reliance on existing system infrastructure rather than change to avoid damage. Agility could relate to resistance and safety by minimizing consequence of a disruption, and to sustainability by helping the system to reorient in such a way to decrease the need for outside investment.

**Reliability** does not improve adaptability or agility, because it has no term about change. It has time as a denominator, thus it can be an outcome of resilience, robustness, security, and resistance but not a contributor. It could contribute to safety if its thresholds align with safety priorities, but there are cases where reliability between suboptimal critical thresholds is more desirable or cost efficient than attempting to have high safety at all times. Improved reliability also contribute to sustainability by limiting the declines of system functions and therein the outside investment needed to sustain it.

**Resilience** can only manifest when recovery is needed, and thus can be combined with concepts related to failure like resistance, robustness, safety, and security, but does not contribute to them. Improving resilience will improve reliability by minimizing time outside thresholds, and improve sustainability by reducing the need for outside investment. Though adaptability and agility contribute to resilience, resilience can contribute to them only conditionally, because resilience may arise from either perseverance or change. Agility and adaptability capture a system's ability to recover by changing, but we note that there is no system concept that captures a system's ability to recover by perseverance alone. Perseverance can be implied in resilience, but is not synonymous with it.

Increased **resistance** improves reliability, safety, and sustainability by decreasing the amount the critical function declines when facing disruptions. Resistance does not involve aspects of change or consider the recovery process after a disruptions, thus it cannot contribute to agility, adaptability and resilience. Resistance is only necessary if security is disabled, therefore its capabilities do not affect security. Finally, resistance is distinct from robustness because resistance incorporates any corresponding decrease in critical function after pressure is applied to the system, therefore it has a conditional relationship with robustness because they both represent an ability to withstand pressure, robustness in totality, and resistance by degrees.
**Robustness** prevents system functionality from experiencing disruptions, thus fully robust systems have no need for resilience, agility, or adaptability. Robustness can improve resistance by increasing the pressure necessary for a disruption to become an impact, and avoiding system disruptions will increase safety, reliability, and sustainability. Finally, robustness and security are similar, but the system components exhibiting them are different – robustness refers to the critical function itself, and security to some external protection that must first be compromised before the system itself is vulnerable. Therefore, improvements in robustness will not affect security.

**Safety** measures the probability and consequence of a disruption occur to the system functionality, not the system’s ability to withstand or mitigate the disruption (agility, resistance, robustness, security) or to recover from it (resilience, adaptability). A lower probability and consequence of disruption occurrence will support system sustainability and reliability, thus safety contributes to those concepts.

**Security** can prevent disruptions from arising, thus contributing to safety, reliability, sustainability. Improved security can negate the need for agility, adaptability, and resilience, thus security is unrelated to them. System security can contribute to system robustness and resistance because it increases the overall pressure that can be withstood before the system experiences disruption.

Finally, **sustainability**, like reliability, is measured over time and is thus an outcome of many other features, but not a contributor. Having more stable performance over time without dependence on outside contributions can increase measures of system safety and system reliability.

Figure 2a below represents our evaluation for whether a concept column contributes to a concept row. The table is not symmetrical, and arrows that are not solid denote partial relationships. These relationships are summarized in Figure 2, color-coded by whether concepts are sources or outcomes in various relationships, or for the cases of reciprocity, whether it is conditional or not.

We note that three of the nine concepts both give and receive support in a non-reciprocal manner. The remaining six concepts have reciprocal relationships but otherwise either exclusively give support (yellow) or exclusively receive support (orange). We also note that the two concepts with the least relationships are exclusively causal (with mutual relationships), whereas the two concepts with the most number of relationships are exclusively outcomes (with mutual relationships) – none of the extremes are both give and receive non-mutual support.

There is strong correlation between the concepts that give support (yellow), and the linguistic characterizations of terms that are actions (Table 2), with the exception of resilience. Similarly, there is a correlation between concepts receiving support (orange) and linguistic characterizations of overall performance, with the exception of safety. The “reactions” of our linguistic analysis comprise two of the three terms that have both causes and outcomes in Figure 2. Though not perfectly correlated, Figure 2’s distinctions between the concepts have much overlap with the distinctions made in Table 2, and even more so with the more nuanced linguistic interpretation table in SI3. Therefore, we synthesize this information to propose a generalized conceptual framework relating to all the concepts (Figure 3).
In Figure 3, having agility, adaptability, and resilience supports the other concepts, often mediated by the three concepts in the middle (security, robustness, resistance) that are both give and receive support. Reliability, sustainability, and safety receive support for their realization. The diagram generalizes the concepts according to levels that are more flexible than they appear, with some terms acting as mediators in specific processes, but as inputs in others.

This analysis provides a structure for the process of attaining a system characterized by these terms: e.g., building the skill of agility can help a system become more adaptable, resilient, and reliable. We could view the top layer of concepts (yellow) as deliberate actions or choices taken, the middle concepts as short term consequences or abilities enabled by those actions (blue), and at the bottom, the long-term outcomes (orange). The outcomes, sustainability, reliability, and safety, all characterize the impacts of varying levels of performance over time, but not the reasons or processes that create them – these are provided by the proceeding levels. This conceptual framework demonstrates that the concepts are not mutually exclusive: the structure shows where they contribute to each other and even how they can be used in concert. The conceptual framework can reveal concrete pathways towards improving overall system performance, starting with the choices made.
Providing a better understanding and deliberately consistent usage of these concepts will enable systems managers to evaluate their systems, anticipate and validate the impacts of improvements, communicate their methodologies to other system managers using mutually comprehensible concepts.

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