Measuring the Crowd – A Preliminary Taxonomy of Crowdsourcing Metrics

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ABSTRACT
Crowdsourcing initiatives benefit from tapping into diversity. A vast plethora of disparate individuals, organizations, frameworks and skillsets can all play a role in sourcing solutions to a challenge. Nevertheless, while crowdsourcing has become a pervasive phenomenon, there is a paucity of research that addresses how the crowdsourcing process is measured. Whereas research has advanced various taxonomies of crowdsourcing none to date have specifically addressed the issue of measuring either specific stages of the crowdsourcing process or the process as a whole. As a first step towards achieving this goal, this research-in-progress paper examines crowdsourcing at the operational level with a view towards (i) identifying the parts of the process (ii) identifying what can be measured and (iii) categorising operational metrics to facilitate deployment in practice. The taxonomy advanced is overarching in nature and can be deployed across disciplines. Furthermore, the preliminary taxonomy presented will offer practitioners a comprehensive list of metrics that will enable them to facilitate comparison across various crowdsourcing initiatives.

Categories and Subject Descriptors
C.4 [**Computer Systems Organization**]: Performance of Systems - *Measurement Techniques*; H.4.3 [**Information Systems Applications**]: Communications Applications.

General Terms
Measurement, Performance, Design.

Keywords
Crowdsourcing, taxonomy generation, metrics.

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1. INTRODUCTION
With the move towards seeking solutions outside of the traditional four walls of organizations, the information systems (IS) community is actively seeking to identify antecedents to open innovation and its subsets including crowdsourcing. Crowdsourcing as a contemporary means of problem solving is drawing mass attention from the Internet community. In 2014 big brands such as Procter and Gamble, Unilever, and Pepsi Co increased their investment in crowdsourcing in ranges from 50% to 325% [73]. In the case of Unilever, crowdsourcing presents itself as a means to achieving a target of doubling the business by 2020 in a sustainable manner. The Unilever Foundry IDEAS platform is a key part of the businesses innovation and idea generation strategy for the organization [83]. While an initial definition for the term crowdsourcing was advanced in 2006 [44], historical non-socio technical examples exist of calling upon the wisdom of crowds including the Longitude Prize of 1714 [77]. Jeff Howe defines crowdsourcing as the "*act of a company or institution taking a function once performed by employees and outsourcing it to an undefined (and generally large) network of people in the form of an open call.* [44]. Recent research has extended the definition to also include situations outside of pure "business" outsourcing such as charity, philanthropy and government initiatives. Since 2006 a plethora of other definitions have been advanced from research [19; 27; 53]. Moreover, specific definitions for crowdsourcing have been put forward in certain industry specific contexts such as the software development industry [79]. Within the context of different sectors, such as innovation and scientific research, crowdsourcing has been utilised as an effective innovation and problem-solving tool [30; 60; 61; 71; 82]. Diversity in itself can have a major effect on organizations and their revenue streams [47]. However, with this great diversity come the challenges of establishing metrics and benchmarking. According to Kerzner you cannot correct or improve something that cannot be effectively identified and measured [48]. The preliminary taxonomy presented herein proposes to address one part of this challenge (i.e. the identification of metrics) at an operational level. Taxonomy generation represents a means by which relationships amongst concepts can be understood through structure [35].

With the advent of crowdsourcing organizations can now use information systems technologies to source ideas and solutions from the crowd. Crowdsourcing is used for many different types of challenges. Numerous examples exist of successful crowdsourcing initiatives including iCancer UK, Dell Idea Storm, IBM Jams and Lego Ideas to name but a few. Furthermore,

crowdsourcing can be used by governments for the purposes of public participation, the sourcing of new project partners, the sourcing of new ideas and the vetting of solutions [20]. The crowd can also be used in the sourcing of funds/venture capital through the guise of crowdfunding. Information systems research plays an important role in this process, as IS facilitates the optimization of crowdsourcing [59]. This is of particular importance where efficiency is critical. Bayus notes that many companies have rushed to implement crowdsourcing communities without fully understanding their effectiveness [12]. It follows that the IS component in the crowdsourcing process is of immense importance to understanding and refining the efficacy of such initiatives. Despite recent advances in research, available models and technologies for crowd organization and control are still in their infancy [18]. Geiger notes that existing use cases fail to provide a comprehensive picture of the overall phenomenon [32]. Crowdsourcing is seen as a new means by which traditional projects and challenges can be solved in a new and more dynamic way. Projects in both the public and private sectors face numerous challenges as to their instantiation. For instance, traditional processes can be limited by a finite number of suggestions/responses to a challenge. The limited size of the organization seeking a solution can act as impediment to the number of potential solutions presented. Furthermore, traditional projects can suffer challenges in their project selection mechanisms [14]. Projects can also experience difficulty in enabling multidisciplinary approaches where different types of actor seek to participate such as government and academia [55]. It is posited that crowdsourcing can assist individuals and organizations in overcoming such challenges.

This research is motivated by three main factors. Firstly, whereas there are numerous crowdsourcing taxonomies presented in research, none provide guidance as to what operational crowdsourcing metrics to use in practice. Secondly, none of the taxonomies presented to date have disaggregated the crowdsourcing process to a level sufficient for the purposes of identifying what can and should be measured. Thirdly, the taxonomies advanced are not overarching in nature and cannot be used across all types of crowdsourcing. In the absence of a clear understanding of the components that form the entirety of the process, it is impossible to form a taxonomy of metrics. Based upon these motivating factors we propose the following research questions:

RQ1: What are the different parts of the crowdsourcing process and their associated metrics?

RQ2. How are the metrics identified best reflected in an overarching taxonomy?

This paper begins with an introduction to metrics (section 2). Thereafter, the various components that make up the crowdsourcing process are identified through thematic questions (section 3), followed by the research method (section 4) and a preliminary taxonomy of crowd metrics (section 5). Finally, conclusions and avenues for future research are outlined (section 6).

2. IDENTIFYING METRICS

The Oxford Dictionary defines the noun "metric" as a "system or standard of measurement". In a business context this is extended to include a set of figures or statistics that measure results [66]. Defining and specifying a set of recommended operational metrics for a process is not a new phenomenon. In areas such as software development, the adoption of a set of operational metrics throughout the lifecycle of a piece of software is a common task completed by developers [8; 28]. Carlson and Kavanagh state where addressing metrics and analytics the organization needs to address what problems in the organization are worth solving. Also the organization can examine the opportunities that exist for enhancing organizational effectiveness [21]. Whereas most model development to date in crowdsourcing has been practice driven, IS research is seeking to formalise crowdsourcing models in an effort to advance a theoretical grounding of the area [26].

In the context of crowd engagement, organizations have the opportunity to source solutions to challenges and increase their own operational efficiency through the use of crowd technologies. In adopting a taxonomic approach to this research we are exclusively focused upon the identification of operational metrics rather than high-level tactical or strategic indicators such as KPI's, critical success factors, principles and goals. Furthermore, to establish metrics relevant to the crowdsourcing process we also draw on literature arising from other collaboration and production processes such as supply chain management [37], open source software development [86], collaborative innovation [81] and co-creation [6].

3. WHAT IS CROWDSOURCING?

Having reviewed the literature relating to crowdsourcing across domains the authors noted the same recurring themes of interest across disciplines. We synthesised seven questions to act as a lens through which the individual parts of the process can be identified at a sufficiently high level of abstraction for the purposes of the identification of metrics. An examination of the crowdsourcing literature has provided a map of the different crowdsourcing process stages, sub processes and participation architectures. Crowdsourcing is viewed from different research perspectives including the organization, the technical, process centric and human centric perspectives [40]. In advancing metrics the preliminary taxonomy is required to take into account all models and frameworks irrespective of their originating paradigm. In some cases crowd taxonomies are advanced from a sectoral viewpoint such as government. In other examples different disciplines have taken a viewpoint as to the problem space such as human resources [39], marketing [88] or human computation systems [70]. In seeking solutions various process stages are completed through a platform/participation architecture. Accordingly, it is necessary to begin with an accepted definition whereby all process components are available for measure. Estrelles-Arolas and Gonzalez advance the following comprehensive definition of crowdsourcing synthesized from the body of research available [27]:

"*Crowdsourcing is a type of participative online activity in which an individual, an institution, a non-profit organization, or company proposes to a group of individuals of varying knowledge, heterogeneity, and number, via a flexible open call, the voluntary undertaking of a task. The undertaking of the task, of variable complexity and modularity, and in which the crowd should participate bringing their work, money, knowledge and/or experience, always entails mutual benefit. The user will receive the satisfaction of a given type of need, be it economic, social recognition, self-esteem, or the development of individual skills, while the crowdsourcer will obtain and utilize to their advantage what the user has brought to the venture, whose form will depend on the type of activity undertaken*" [27] p 197.

We highlight the various components of crowdsourcing through the presentation of a series of seven questions that arise in the above definition and indeed other definitions of crowdsourcing. These questions have been synthesised from recurrent themes identified in the body of crowdsourcing literature across domains.

i. What type of activity is crowdsourcing?

The majority of crowdsourcing definitions advanced define the activity as an online web 2.0 based process [75]. However, examples of crowdsourcing exist where no technologies or software ecosystems are used [62]. Furthermore, certain crowd systems use SMS communications through GSM [36]. Many of the traditional approaches to platform generation in crowd engagement find their origins in areas such as collaborative computing and computer-supported cooperative work. However, the majority of contemporary scientific crowd initiatives feature the process initiator deploying their own web 2.0 platform or through using a third party platform. This is predominantly the case with innovation challenges where the project initiators manage their own platform or portal. Crowdsourcing can be a linear or iterative process. In human computation systems there is evidence of processes using iterative improvement cycles [70]. We conclude that crowdsourcing is a largely but not exclusively online activity.

ii. Who are the crowd?

No crowdsourcing definitions place a minimum or maximum limit as to the size of a crowd. However, the crowd is defined in some instances as generally a large network of people [44]. Crowds can pre-exist the formation of a platform in the form of social groups and communities. However, from the crowdsourcing perspective the crowd only become active where engaged through an open call in the crowdsourcing process. The crowd can be of varying sizes and levels of internality or externality to the initiator organization. Yang notes that crowdsourcing involves an "Internet scale community" [89]. Government crowdsourcing is one such example. A crowd can be requested to engage in a challenge via a platform or self assemble in light of certain types of challenge through on-line communities. The crowd can self-specify who is to be involved as is exampled in other types of online community formation such as "curation" [69] and "mutual assessment" [76]. In practice we see examples of the crowd displaying varying levels of skill in their participation. Some tasks are offered to the crowd that require minimal skill such as with Microtasks. Other examples such as with software testing and development require the crowd member to have advanced or specific skills. In almost all cases the crowd participate on a voluntary basis. Even in the case of internal crowdsourcing offered to the employees of organizations crowdsourcing initiatives are presented seeking voluntary submissions. We conclude that the crowd is of varying size, skill and level of externality to the initiating organization. The crowd can also self assemble of it's own volition or through a request received from others.

iii. Who commences the process?

Within IS literature various terms are used to define the person or organization that engages the crowd in seeking solutions. Terms exist as diverse as the process requestor, initiator, focal agent, crowdsourcer and crowd user [15; 27; 36; 57; 84]. In the context of business, the process initiator generally takes the form of an individual or an organization. For the purposes of describing the process we adopt the term 'process initiator' put forward by Estrelles-Arolas and Gonzalez [27]. We posit that rather than treating the initiator as external to the process, the individual or organization that commences the process should be regarded as an integral part of the crowd. This is by virtue of the fact that as a participant the initiator forms part of the participating crowd. In many instances the initiator participates in the process by either identifying challenges / tasks in need of resolution, incentivising contests or indeed selecting winners. The process initiator through a platform engages a crowd through broadcasting an open call seeking solutions. However, from the examples examined from practice it is incorrect to assume the initiator becomes inactive after posting a challenge. In almost all cases they continue to form a dynamic part of the crowd process and decision mechanisms.

iv. How is the problem or challenge communicated to the crowd?

Open call is the term used to describe the means of broadcast to the crowd. The term can be somewhat misleading where "open" does not necessarily imply that the broadcast to the crowd is not targeted at a particular demographic or subject to certain restrictions. Wexler describes a call process as targeting either "an undifferentiated mass; or narrow, for instance calling on those who debug computer viruses" [87]. For example in micro tasks placed upon Mechanical Turk, crowdsourcing contests can be restricted to "Turkers" of a particular nationality or skill-set. Such calls are not truly open in nature whereby restrictions are in place as to who can participate. We observe that in most cases the challenges are communicated to the crowd in the form of an open call. However, in some cases the call is not truly open in nature.

v. Through what mechanism do the crowd participate?

The platform/participation architecture provides the basis for crowd interaction. Crowdsourcing projects are complex in nature and differ from traditional projects in numerous aspects. According to Kerzner complex projects vary in "size, dollar value, uncertain requirements, uncertain scope, uncertain deliverables, complex interactions, uncertain credentials of the labour pool, geographical separation across multiple time zones, use of large virtual teams" amongst other differences [48]. To deal with such complex interactions participation mechanisms are required.

Various different tools and strategies have been deployed in practice through such mechanisms. A core aspect of the process of complexity reduction is the use of efficient participation architectures within contests [86]. The astute process designer can build the process in such a way so as to improve performance based upon a continual response to the feed of data obtained from the process cycles. In one such example regarding Topcoder.com, Boudreau at al note from interview data that problem designers have to create challenges that have well-defined outcomes so that automated test suites can be used to assess performance [17]. The mere presence of a participation mechanism is not a guarantee of success. Moreover, how we design the mechanisms is of critical importance to outcomes. We note that the crowd compete and collaborate through platforms and participation architectures that are designed to reduce complexity and where possible increase efficiency.

vi. How do the crowd contribute?

The crowd physically contribute within the ecosystem through various means. Examples exist in crowdsourcing of crowds voting a winner. In other examples an administrator or expert picks a winning idea or potential solution in response to a challenge.

Crowdsourcing platforms contain varying scales of interaction. One such scale is collaborative and competitive interaction [4; 16]. Competition based initiatives are also known as "*tournaments*". Afuah and Tucci describe tournament-based crowdsourcing where each agent from the crowd self-selects to work on its own solution to the problem, and the best solution is chosen as the winning solution [2]. In contrast another form of crowdsourcing - "*collaboration based crowdsourcing*" - exists where self-selected members of the crowd "*gang up*" (work together) on the problem to solve it, and the result is one solution from the crowd [2]. Competition and collaboration are not exclusive. Both competition and collaboration are evident at various stages in the same process such as collaborative design through the crowd [68]. Quite a degree of construction and hierarchical control can be exhibited in the design of the participation architecture through the platform. It is in these various controls that we can identify various metrics.

A solution can be identified by the crowd through either one iteration of the selection process or after multiple sprints. With each new process cycle options are narrowed until a final output is selected. Such hardening sprints are common in project management methodologies such as agile software development. Within the crowdsourcing process participation can be well bounded with clearly defined problem requirements. However, by contrast, examples also exist in crowdsourcing of loosely defined objectives. Through the use of different modules in the crowd process different levels of bounding can be applied to different stages of the process. Modularity and task disaggregation is present in crowdsourcing platforms/participatory architectures in various capacities. Firstly, tasks can be divided up with varying degrees complexity or granularity. Secondly, different stages of the process can be modularised so as to reduce complexity. Lastly, modularity in crowdsourcing can facilitate multi-tasking or parallel task completion. Baldwin argues that "modularity is important for collaboration in design because separate modules can be worked on independently and in parallel, without intense on-going communication across modules" [11]. The same can be said of crowdsourcing. The bounded and modular nature of the crowd processes can facilitate both the measurement of sub processes and the process as a whole. From the literature and practice examples, we can observe that the crowd contribute through participation in the process either concurrently or independently of each other, in various types of modules with varying levels of task bounding.

vii. What remuneration or recompense does the crowd receive for participation?

Archak notes that designing efficient crowdsourcing mechanisms requires an understanding of incentives and strategic choices made by participants [7]. The process can be driven for intrinsic reasons such as to assist a societal objective. In the context of both public and private scientific research examples exist of citizen science platforms where there are no rewards and no remuneration for participation changes hands. The process can be motivated by extrinsic reasons such as financial reward for participation as in the case of micro-tasking websites [50]. Likewise innovation portals include remuneration or cash prizes for participation. Rewards affect behaviour as evidenced by the relationship between payment and contestant performance [7]. This in turn also has an impact on quality of outcomes. Whereas incentives relate to strategic and tactical concerns base measures relating to incentives are of operational concern. We conclude that in order to contribute to the efficiency of such platforms it is important to measure the types and, where appropriate, the amount of incentives on offer.

4. RESEARCH METHODOLOGY

In seeking to identify a preliminary taxonomy of metrics a substantial literature review was conducted of crowdsourcing and related domains. Furthermore, literature regarding taxonomy/typology generation was reviewed. We adopted a reflective over-arching approach to reviewing the academic literature and as a result, examples emerged not only from an information systems perspective but also from social networks, labour economics and human resources literature. Inclusion criteria included peer reviewed journal articles that define crowdsourcing or advances models and frameworks, identify crowdsourcing or open innovation process components and/or provide details of collaborative production and design processes. Unlike the systematic approach the present method used a thematic approach in the evaluation of various literature strands relating to crowdsourcing. The literature review was completed in line with processes suggested by [85] and [54]. In particular, (i) a plan was prepared, (ii) searches were conducted, (iii) papers were screened for relevance and (iv) data was extracted.

In completing this research the researchers utilised several EBSCO databases including Business Source Premier and Emerald Management Xtra and other electronic databases such as ACM Digital library, ScienceDirect, Springerlink, Elsevier, Wiley, etc. that contained research publications, i.e. peer-reviewed journals, conference proceedings, articles etc., valid to the study. Searches were conducted against the core terms related to crowdsourcing in other databases including Scopus and the Web of Knowledge. Whereas a core body of literature is recognised in the area of taxonomy generation, a list of keywords was prepared for the purposes of refining the body of literature on crowd research. Search terms included: crowdsourcing, crowdfunding, crowd science, citizen science, crowd voting, wisdom of crowds, microtasking, co-creation, collective intelligence, collaborative innovation, participation architectures, and peer production.

Exclusion criteria included crowdsourcing initiatives that used crowdsourcing as the method for research evaluation without the specific discussion of the construction of the crowdsourcing process. For example numerous research projects gather data through Amazons Mechanical Turk without substantial discussion as to the use of crowdsourcing in the research process. Furthermore, research that mentioned crowdsourcing as a tool used without discussion of the system or its components was disregarded. The resulting literature review was used in the identification of crowdsourcing metrics spanning the four headings outlined in Table 1. Secondly, with regard to the taxonomy generation methods used, key approaches used by [10] and [64; 65] were employed in the process. Taxonomy refers to a conceptually or empirically derived grouping [65]. The method was also led by examples of cross disciplinary focused taxonomy generation as used by [58]. Furthermore, examples of taxonomy/typology generation in crowdsourcing were used by [33; 34; 74]. Rouse states that a taxonomy is a classification scheme, through which a phenomenon can be explored by classifying *"like with like"* and separating *"unlike*" [74] p4. To this end examples exist in the taxonomy generation body of literature as to the types of classification groups employed. In the present research the process was divided into components (rather than subtypes) prior to the categorising of metrics.

According to Nickerson approaches to taxonomy generation can fall into three forms namely "*inductive, deductive and intuitive*". Whereas the inductive process can be supported by statistical analysis the deductive approach derives a taxonomy from theory or conceptualization [65]. In this case the taxonomy is conceptualised by the identification of process components from literature and their comparison against metrics used in practice. This is achieved through a first principles approach. The taxonomy method used should be useful and take into consideration alternative approaches and reduce the possibility of including arbitrary or ad hoc dimensions [65]. As to the qualities of the taxonomic approaches used herein the categories listed are developed from a parsimonious approach whereby no duplicate features or indicators were replicated across categories. Alternate approaches to taxonomy generation were considered. The present method was selected based upon its relevance to the qualitative literature review employed. The utility of the taxonomy herein is justified where no other taxonomy purporting to offer operational metrics has been provided by research to date.

The research herein also involved examining web resources such as blogs, forums, social networking services and crowdsourcing portals. This task was completed so as to review both community crowd schemes and several large-scale crowdsourcing portals in use. This provided an opportunity to review new crowdsourcing and open innovation platforms not currently addressed in the greater body of crowdsourcing literature. Several crowdsourcing portals were examined as to whether or not the four categories of metrics and associated indicators were the subject of measurement within the platforms. Where some metrics and indicators were not expressly apparent from the platform interfaces, deductions were made from other information available as to whether or not specific metrics were in use. Information was obtained regarding portals used by IBM, Amazon, Unilever, Medtronic and Dell.

In the specific case of Amazon Mechanical Turk various metrics are evident from the portal and associated research. Turkers identities are largely shielded. However, from the administrator side of the portal much more data about participants is visible. Also certain platform providers enforce minimum participation requirements such as age and nationality of the participant. In particular, the party setting the human intelligence task "HIT" has the ability to view rich analytics and data on the platform including information about "Turkers" work such as communicativity, generosity, fairness and promptness. From specific research regarding the platform, data has been obtained as to nationality, age, gender, education, HIT's completed, household income levels [45] and furthermore as to remuneration, quality, errors and biases within the process [46]. Accordingly, examples of metrics encompassing each of the four categories of are evident within the portal. Through repeating this process over several portals the existence of each of the indicators under each of the four categories of metric was confirmed.

5. PRELIMINARY TAXONOMY OF CROWDSOURCING METRICS

After presenting the seven questions above we note that four categories of metrics emerge. As is evident from the literature, metrics can be identified and measured through the platform and the processes. In taking a taxonomic approach to advancing crowd metrics, four categories (see Table 1) are identified from the crowd process, namely metrics regarding crowd membership, crowd platform, crowd incentivisation and crowd interactions and outcomes. Although some of the indicators outlined in Table 1 can also apply to the tactical and strategic levels of crowdsourcing, the indicators at the operational level are included where appropriate.

The metrics are discussed in more detail as follows:

i. Crowd Membership Metrics

The true enabling aspect of crowdsourcing comes from both the diversity of the participants and the means of their interaction. Measuring crowd membership can tell initiators core truths about where their successes are coming from and who is playing a major role in that success. Crowd members can be of diverse age, gender, nationality/residency, and skillsets. Furthermore, as outlined in section 3 above examples exist in crowdfunding and crowdsourcing of participants offering suggestions from inside and outside initiating organizations such as with IBM Idea Jams.

Table 1. Preliminary Crowdsourcing Metrics

Metric	Indicators
I. Crowd Membership	-Crowd size -Age -Gender -Nationality/residency -Skill, knowledge, expertise -Individual v corporation -Identity -Internality or externality
II. Crowd Platform	-Cost -Reliability -Reach -Capacity & storage -Efficiency -Security -Complexity -Types of interaction method -Quality of experience
III. Crowd Incentivisation	-Types of incentive -Amount of incentive
IV. Crowd Interactions & Outcomes	-Tasks /Challenges created -Interactions -Time spent on platform -Time to complete tasks -Number of process cycles -Outcomes and outputs -Trust measurements

Crowdsourcing and crowdfunding platforms feature contributors who identify themselves through an open identity or participate through anonymous user profiles. Nationality and residency can be of particular importance whereby different governing Intellectual Property (IP) and copyright rules affect participants. It is possible to be of a particular nationality yet have different IP regulations apply to the crowdsourcing contest by virtue of a different country of residence. For certain crowdgov competitions in the United States participants not only have to reside in the US but are also

required to be US nationals [22]. Having a diverse crowd increases the potential for different types of solution. Furthermore, as demonstrated by Lakhani the diversity of locations can have an effect on the results whereby the best results can come from outside the primary sourcing domain [52]. The process initiator has the ability to make cost savings by outsourcing tasks to markets where cost efficiencies can produce faster results of higher quality at a fraction of the traditional price over the completion of the tasks locally. However, with this broad and diverse reach comes a word of warning. Due to the nature of emerging markets a variety of commentators have identified potential ethical issues associated with crowdsourcing and labour. A potential exists for the exploitation of workers from emerging markets in an unchecked crowd engagement environment [41]. Accordingly, it is prudent for certain types of crowd initiative to measure the type of diversity as to the crowd membership.

ii. Crowd Platforms Metrics

Platform metrics can be categorised at a higher level of abstraction into nine categories of metrics relating to the platform namely cost, reliability, reach, capacity and storage, efficiency, security, complexity, types of interaction method available and quality of experience metrics. According to Nguyen technical challenges are faced in operating infrastructure and large scale support for crowdsourcing initiatives [18]. The measures pertinent to evaluating platforms range from operational costs to quality of the user experience. From an information technology perspective we can look at areas such as lean manufacturing [63], supply chain management (SCM) [37] and software development [28] in establishing metrics relevant to platform operation. Costs bearing measure can include the cost of crowdsourcing software, the development team, operations staff and hosting expenses. Although crowd platforms can be paper based a vast majority of the present well known platforms incorporate the use of Web 2.0 technologies. IS research has advanced various measurements for use within information systems platforms. Examples include bandwidth, up-time, size of administrator backlog, administrator response time, platform reach, user permission types, administrator levels and bug/error counts. One of the most basic counts of critical importance within software-enabled ecosystems is bug or error counts. This data can be used to help improve operational efficiency of the web 2.0 or software based platforms.

From the software perspective further metrics are available such as lines of code, quality assurance indicators, coupling between objects and weighted methods per class [9]. The measurement of platform reach can be examined under two headings. Firstly, can the platform access all markets to ensure maximum diversity? Examples exist of certain websites and communities displaying access restrictions to certain types of users. Secondly, can the platform be accessed through multiple types of technology or through easier forms of access? Web 2.0 platforms can be limited in terms of their outreach as to all types of social demographics. In developing nations there can be much greater access to SMS technologies than web 2.0 and the Internet [38]. It follows that the measurement of platform types and the extent of platform reach are important considerations for measurement purposes. The metrics outlined are often presented as simple numerical volume counts or percentages over time. Most major hosting providers in offering services present up-time as an example of system reliability. Furthermore, capacity and storage measurements such as bandwidth, storage space and the associated metrics of upload/download speeds can be a measure of the efficiency of such platforms. In the present context such a metric is of particular importance to large-scale crowdsourcing/crowdfunding websites with high levels of traffic. Up until 2013, for example, Kickstarter had attained over one million community members [49]. TaskCn amassed almost 3 million registered users by 2010 [56]. In these specific cases capacity is a measure of concern to administrators.

Efficiency metrics are generally associated with measurement at the tactical and strategic levels. However, certain efficiency measurements exist also at the operational level. Literature on lean production identifies various wastes related to efficiency including overproduction, waiting/queuing, transport, extra processing, inventory, motion, defects and under-utilisation. Accordingly, it is posited that the existing metrics of lean production highlight certain operational efficiency metrics that can be reflected upon the crowdsourcing process at an operational level. According to [28] the scope of software metrics also includes security metrics and complexity metrics. Operational security metrics are exampled by counts such as the number of denial-of-service attacks on a website over a time period. Complexity metrics are evident in platform design and the different types participation cell types can be created within environments. Such cells can be differentiated by the types of interactions available within that cell or the administrator permissions set. For example can the administrator review comments or interact as an expert? Furthermore, different parts of crowdsourced innovation contests can provide members with a chance to vote at certain stages and comment at other stages of the process. Platform administration quality can be measured through ticket response times, ticket backlogs and administrator permissions. Such metrics are evident in the measurement and management of global virtual teams (GVT's) within information systems. The user experience of interacting with the platform and operational model can also be measured. Indicators in this type of metric category also find basis in areas such as website usability, design and performance metrics [67]. Research exists presenting Quality of Experience measurement (QoE) of end users through a participatory platform [23]. In summation the majority of platform metrics advanced above are recognisable in other fields such as human computation, social computing and audience computer interaction and are reflected in the four category headings.

iii. Crowd Incentivisation Metrics

Incentives are a major focal point in present research. However, in the majority of cases the effects of incentives relate more to tactical and strategic concerns rather than operational ones. The type and amount of incentives on offer within crowd systems are critical factors bearing measure [53]. In turn these incentives can be compared against other metrics such as success rates and member retention when looking at tactical or strategic level metrics. Harris suggests that incentives encourage participants to make more accurate judgments [39]. Incentives can be largely divided into two headings, namely intrinsic and extrinsic [72]. Participants are motivated for a plethora of reasons to participate in crowdsourced innovation campaigns. In the case of intrinsic motivations participants can be motivated to participate based upon potential financial rewards for participation. Examples exist of other types of tangible prizes or shareholdings on offer for participation or investment. Shared IP rights and licence dividends can also assume a form of payment. In the case of extrinsic motivations the crowd can be motivated to innovate by reasons other than monies (intangible motivations) [25]. Instances exist of crowd innovation initiatives in disaster relief, social enterprise and rescue missions [29; 31]. At an operational level it is necessary to measure the type and amounts of incentives used.

iv. Metrics for Crowd Interactions and Outcomes

Where a process has been put in place through a platform the crowd require mechanisms by which they can interact and make decisions. These mechanisms form part of the participation architecture and its associated outputs. The various interactions and outcomes have been categorised into eight headings namely; tasks /challenges created, interactions, time spent on platform, time to complete tasks, number of process cycles, outcomes and outputs and finally trust measurements. Within the process crowd members compete and collaborate to achieve process outcomes. These methods of interaction can be monitored through various metrics. Examples located from crowdsourcing and social media platforms include the number, correctness and types of comments, submissions, votes, likes, dislikes, aggregations, shares, interactions, donations and investment types or amounts [5; 42]. Measurements can be completed as to the number of problems or challenges selected by the crowd and also the associated level of granularity [43] set as to the problem or tasks at hand. For example with micro-tasking generally a low level of granularity in involved where problems or tasks are put to the crowd. Within the task or problem design the process initiator describes his specific level of expertise required to complete the task and also the level of granularity as to the parts that comprise the challenge. This approach in disaggregating tasks is an important feature in innovation challenges.

Other types of interactions can be measured such as a member's active and passive presence on the participatory platform. Examples exist of crowd members who are happy to play a passive role [24] by offering suggestions whilst not necessarily voting or seeking rewards for participation. They may occasionally enter the platform to offer cursory interactions. More active members can spend a substantial amount of active time on a platform participating and engaging in the processes at the core of crowdsourcing. The number of overall and constituent process iterations can be measured as to their number and duration. This in turn will allow a comparison of the length of individual process segments such a problem formulation against the total time duration of the overall process. Simple metrics relating to outputs such as numbers of successes and failures can be counted where clear goals are established from the outset. This is the case with regard to many crowdsourced innovation initiatives where a target is set from the outset and the process either succeeds or fails in the form of an output or the generation of IP, e.g. copyright, trademarks or patents.

Correlations have been shown between crowd members trust and process outcomes. In an innovation context the participant requires safeguards to either protect them from idea theft or reward them sufficiently for taking the associated IP risks in participating. Allahbakhsh et al points out that reputation and expertise are factors within crowdsourcing systems [3]. They relate specifically to the worker or crowd member's profile. Archak presented an empirical analysis of determinants of individual performance in crowdsourcing contests [7]. In so doing, the relationship between member rating and skills was examined. Within innovation contests the reputation of crowd members can be influential in varying degrees. Where a crowd is vetting potential problems and solutions, a degree of expertise or trust can be required in the evaluation process. By advancing Wikitrust and Crowdsensus, Adler et al investigated the measurement of user reputation [1]. The reputation of users is computed according to the quality and quantity of contributions they make. In crowd systems where a high element of collaboration is desired such a measurement can be appropriate in seeking to influence future crowd behaviour so as to increase impact. Kosinski et al noted a correlation between higher reputation and higher performance. [51]. Accordingly, trust measurements such as reputation scores are an important measurement point within the process.

6. CONCLUSIONS AND FUTURE RESEARCH

Building upon the existing literature, this research represents a first principles approach to identifying operational metrics in crowdsourcing. This paper makes an important contribution to the existing crowdsourcing body of knowledge on several fronts. Firstly, the parts of the crowdsourcing process bearing measure have been identified. Secondly, a taxonomy of metrics appropriate to crowdsourcing has been presented where none has previously existed. Finally, a taxonomy is now available with which to compare differing crowd frameworks. It is also possible to compare crowdsourcing against other competing forms of peer-production (e.g. open source and inner source [78]). Components that form part of the crowdsourcing process can now be compared in different initiatives across disciplines. In practice the taxonomy advanced prompts a checklist of metrics that the users of crowdsourcing or platform developers can apply to confirm that the process is sufficiently measured. Not only so as to measure operational efficiencies internally but also to facilitate comparing initiatives across projects and domains. The conceptualised taxonomy is also derived from theory where by contrast many crowdsourcing taxonomies have been grounded from practice. This represents a strong parsimonious approach to taxonomy creation.

We provide the initial foundations upon which future tiers for crowdsourcing metrics can be developed. Subsequent research will seek to identify metrics at the tactical and strategic levels of the organization. There are a great number of strategic metrics regarding crowdsourcing that exist in practice yet to be identified. However, as a starting point a foundation is required before other amalgamations of core metrics and associated KPIs can be advanced. Where the numbers of measures available becomes excessive it is posited that in the absence of a comprehensive taxonomic approach at these tiers, formulas can be advanced as to the construction of tactical and strategic metrics. Future work will seek to validate this model in practice. It is posited that case studies present a suitable research approach for the requirements of these types of study [90]. In order to identify other potential metrics case studies will be completed with users of crowdsourcing. In the specific context of this research, scientific research funding agencies will be used as exemplars in the validation of the metrics presented. The research proposes to deploy several methods of data collection [13] to gather information from several crowd engaged entities. In certain cases Likert Scales will be utilised for the measurements in question. However, as is evident from present research, other types of ratio measurement or more complex forms of measurement scales will be required for the purposes of evaluation.

Further research is warranted in respect of crowdsourcing. Firstly, crowd enabled systems thrive in a culture of process transparency and it follows that an equal level of transparency is required as to what is measured in crowdsourcing and how it is measured within the process. Such non-process specific issues can be addressed in future research. It is also possible in future research to extend the

focus to areas such as crowdfunding or to test the taxonomy against sector specific types of crowdsourcing such as crowd government. Finally, and most importantly, research is required on fine-tuning metrics across different sectors for the purposes of comparisons. Key measurement points within government backed crowd initiatives differ greatly from those of enterprise. Whereas the categories advocated in this preliminary matrix cover operational metrics at a high level of abstraction, further investigation is required into what sub-processes might also require evaluation at lower abstraction levels.

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