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A MODEL FOR MEASURING INTERFACE HEALTH BETWEEN PROJECT STAKEHOLDERS IN COMPLEX CONSTRUCTION PROJECTS

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Abstract: A healthy project can be defined as a project performing as expected with the project stakeholders working towards the project goals as a team. According to the PMI's Pulse Report (2013), on average, two-in-five projects do not meet the original project goals, and one-in-five projects are unsuccessful due to ineffective communication. Large scale construction organizations often undertake many projects concurrently, managing various stakeholders, contractors, subcontractors, and vendors simultaneously. In such a seemingly chaotic management environment, project health is directly impacted by miscommunications, time-overruns on information requests, excessive numbers of design revisions, etc. There are traditional quantitative project performance measures for construction projects such as schedule and cost variance, but these methods mostly highlight standard project failure symptoms, are lagging indicators, and don't have the ability to identify emerging problems between project stakeholders that can cause potential project failure. In this conference paper, a model for measuring interface health between project stakeholders with quantitative indicators (qualitative indicators are addressed by the authors in related publications) that can be applied to a wide range of construction projects, and that can be measured by information management system data such as Interface Management, Request for Information, and Change Management is presented.

1 INTRODUCTION

The Project Management Institute's Pulse Report findings showed that "effective communication to all stakeholders" is the most critical success factor in project management, and it is important to all organizations (PMI, 2013). This includes construction organizations. Large scale construction organizations often undertake several projects concurrently, managing various stakeholders, contractors, subcontractors, and vendors simultaneously (Shokri, 2014). In such a chaotic management environment, project health is directly impacted by any miscommunication, time-overrun on the information requests, or an excessive number of design revisions, etc. Therefore, special emphasis needs to be placed on measuring project health between stakeholders which will be termed "interface health" in this conference paper.

Project health in construction is determined according to whether a project is performing as expected by stakeholders or not (CII, 2006). Although each project starts with setting project goals and expectations, at the end there are many projects that fail to meet these predetermined goals and objectives (Tsoukas, 2005). According to Flyvbjerg approximately one in a thousand projects is defined as on target for simultaneously being on budget, on schedule, and delivering the promised benefits (Flyvbjerg, 2014).

In the literature there are several quantitative project performance calculation methods such as cost, quality, and schedule performance indicators. However, these methods are mainly based on the project outcomes;

in other words, they don't show the performance of the project precisely as it is in progress. They are lagging indicators. Besides, these methods mainly focus on overall project performance, and they do not give direct indications of the health and relationship problems between stakeholders. In this research, a framework for measuring interface health between stakeholders during the early phases of a complex construction project is studied. The contribution of this research is that it focuses on interface health measurement between project stakeholders by using project data obtained from Interface Management Systems, Project Schedules, Change Management systems, Document Management systems, and related information technology (IT) and workflow management systems directly.

The outline of this paper is as follows; in the second section, a literature review on the concept of project health, interface management, and interface health is presented. In the third section, research methodology is explained, and then in the fourth, selected interface health indicators and their calculation methods are described. In the fifth section, a discussion and expected future work of this research are presented.

2 LITERATURE REVIEW

2.1 The concept of Project Health

Project health and human physical health have various similarities when it comes to evaluating their health conditions. There would be several symptoms that give clues about the health of a construction project, similar to symptoms that humans would have for their physical health (Weippert, 2009). Humphreys et al summarized these similarities in 7 points. These similarities are namely; 1) state of health influences performance, 2) symptoms can be used as a starting point to quickly assess health, 3) symptoms of poor health are not always present or obvious, 4) state of health can be assessed by measuring key areas and comparing these areas' values to established norms, 5) health changes temporarily, 6) remedies can often be prescribed to return to good health, 7) correct and timely diagnosis can prevent small problems from becoming large (Humphreys, Mian, & Sidwell, 2004; Weippert, 2009). By tracking these similarities, proactive solutions can be taken before poor health conditions occur.

Health of a construction project can be widely determined by tracking project performance against predetermined project goals, objectives, and relationships amongst the project team members. In the literature, project health and project performance measurement related studies are intertwined and correlated. Moreover, Tsoukas (2005) defined project health as the synonym of project performance. It is expected that a project which has an unhealthy project environment, where stakeholders' communication is poor, interfaces are not being managed well, and stakeholders are not working towards the project's aim as a team, would have a poor project performance at the end of its lifecycle. Therefore, there are overlapped indicators that are used as both project health indicators and project performance indicators.

The studies done in project health area can be divided into two groups, namely leading indicator based and lagging indicator based studies. This division is done basically according to indicators that they used in these studies. Lagging indicators are output oriented indicators that are based on events having taken place before. Therefore, these indicators can confirm engineering progress, but do not predict them. With them, project health is calculated after the project is completely delivered or after a specific time period. There are also studies that use leading indicators, which can be defined as input oriented indicators that are based on fundamental project characteristic and/or events that reflect or predict project health. In other words, these indicators can help to detect health problems before they happen. Mainly, these research studies are using qualitative data, such as opinion surveys that use the Likert Scale to calculate leading indicators.

Several models that are related to measuring project health have been proposed in the literature. The most recent significant research on determining health problems in construction projects was conducted by CII in 2006. CII proposed a Project Health Indicator (PHI) tool that contains a questionnaire with 43 leading indicators. Each of these indicators has a hypothesized connection with one or more of 5 outcomes, which are project cost, schedule, quality/operability, safety, and stakeholder satisfaction. By filling out the PHI tool questionnaire with its Likert scale, the health of a project in terms of what may be expected for these 5 outcomes can be estimated (CII, 2006).

Another model for assessing construction project health was proposed by the Cooperative Research Centre (CRC) Project Diagnostics Research Team in 2002. Over the years, the model that they proposed has been converted into a toolkit named “Project Diagnostics”. In this model, a circular process for investigating the health of a construction project is used. Initially, construction projects are assessed by using 30 Key Performance Indicators (KPIs) that are related to 7 Critical Success Factors (CSFs). If the outcome indicates that an assessed project is unhealthy, then the project is examined according to Contributing Factors (CFs) that are associated with each CSF, and Secondary Performance Indicators (SPIs) that are related with each CFs. At the end of these examinations, root causes of the unhealthy project are determined, and remedial activities that are associated with each root cause can be identified. This cycle should be repeated until the project health is measured as healthy.

2.2 Interface Management

In the literature, several different definitions for the terms “interface” and “interface point” can be found. In this research, the term “interface” is considered as “a common boundary or interconnection between independent but interacting systems, organizations, stakeholders, project phases and scopes, and construction elements” (Chen, Reichard, & Beliveau, 2007; Harrison & Hamilton, 2004; Healy, 1997; Lin, 2009; Morris, 1997; Shokri, 2014; Stuckenbruck, 2008; Wren, 1967).

Managing interfaces, communications and deliverables between interface stakeholders of a project can be achieved by applying an Interface Management System (IMS). An IMS consists of an automated workflow engine driven, cloud-based, information technology system using several subsystems like document and database management. A typical IMS hierarchy would consist of three main elements, which are: Interface Points (IPs), Interface Agreements (IAs), and Interface Agreement Deliverables (IADs). In a complex project there can be many IPs between project participants. A typical IP can have many IAs, and an IA could have several IADs. Therefore, in a complex project, there will be numerous IADs.

An IMS can provide information about how well interfaces between stakeholders are being handled anytime during the project lifecycle. Time overruns on the deliverables, or any misunderstanding, information requests, or revisions on the IAs and on the IADs can be tracked and solved in a timely manner. More detailed definitions on Interface Management Systems (IMS) and the components of a typical IMS hierarchy can be found on the Interface Management Implementation Guide provided by Construction Industry Institute (CII) at 2014 (Chan, Leung 2004, Shokri 2014).

2.3 Concept of Interface Health

Interface health is a subset of project health, since management of interfaces between project stakeholders is one of the main components that directly affects the overall project health. Interface health can be defined as the overall health of all the connections between two interface stakeholders in terms of meeting the requirements of the IAs they have, and working as a team for predetermined project goals. Therefore, in order to measure project health, first, interface health between project stakeholders should be measured. In figure 1, the connection between project health and interface health is presented as a triangle.

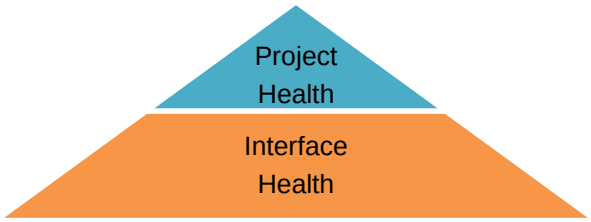

Figure 1 Triangle of Project health to interface health

In a typical complex construction project, there would be many project stakeholder pairs whose responsibilities in the project are directly interdependent. Therefore, specific attention should be given to

interfaces between project stakeholders in order to achieve overall healthy projects. While an IMS is used for managing relationships, agreements, and interfaces between stakeholders, it can be also a great source for measuring interface health and overall project health.

An example network representing project stakeholders and their interfaces between is given in figure 2. In this network, nodes are representing project stakeholders, while edges are representing all interfaces between them. For the simplicity of this example, all project stakeholders are accepted as equally important and have the same amount of interface points between each other.

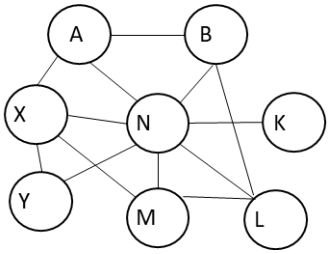

Figure 2 Example network where nodes are project stakeholders and links are the interfaces between them.

Interface health between two stakeholders is bidirectional, and each direction can have a different interface health result. In other words, interface health value between stakeholder A and stakeholder B can be different for each stakeholder. In Figure 2, an example of different interface health measurement between two stakeholders are presented with the color codes. In other words, they may experience the health of the relationship differently.

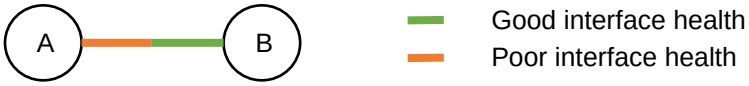

Figure 3 Interface health representation between two stakeholders

In typical complex construction projects, there would be several project stakeholders involved, and number of stakeholders would change in different project phases. Theoretically, if there are “n” number of project stakeholders involved in a project, the number of paired combinations between these project stakeholders can be found with the formula given in Equation 1, where “n” is the number of the project stakeholders.

[1] $C(n,2) = \frac{n!}{(n-2)!2!}$

However, since interface health can be measured bi-directionally, the order or the combination of the project stakeholders would matter in this research. Therefore, the maximum number of calculation between pairs would be the double amount of the result reached by using Equation 1. In other words, since the order of the pairs is important in this research, instead of combination formulas, the permutation formula which is given in Equation 2 where again “n” is the number of the project stakeholders, should be used.

[2] $P(n,2) = \frac{n!}{(n-2)!}$

For example, if a project involves 10 project stakeholders, the theoretical maximum number of links that can be created would be 45, and in that network, the maximum number of interface health measurement calculations that need to be conducted would be 90. Manually collecting data and conducting these calculations for a project that has a large number of stakeholders would be time consuming. One way of overcoming this problem is assessing overall project health by using IMS and IT system data related with those stakeholders.

3 RESEARCH METHODOLOGY

Industry partners presented the need to measure health that this research addresses. To address that need, a literature review on project health was conducted to define the problem, scope and objectives that have been summarized in the preceding sections. The following sections of this paper describe a methodology that is followed for the scope of the preceding research described in this paper. First, indicators that can be used for measuring overall project health are selected. Then, interface health indicators are defined by using project health indicators as a guide. After presenting the expected data source for each indicator, an example calculation for one of the interface health indicators is explained. Finally, an overall interface health measurement equation is explained.

In this conference paper, the main focus is initially on the design phase in the project lifecycle. This research can be expanded to the whole project lifecycle as future work. While selecting project health indicators and defining interface indicators, two main assumptions are made. These assumptions are;

1. Complex construction projects are designed and built by many project stakeholders who have interfaces between each other.
2. Project stakeholders would use shared project management systems that would include but not be limited to; Request for Information system, Change Request system, Interface Management system, Schedule management system, Document Management system, and shared 3D design models. These systems are not required to be sophisticated software, but data related with those systems need to be available.

4 SELECTED INTERFACE HEALTH INDICATORS AND CALCULATION METHODS

Initially, 12 leading health indicators that can be used for measuring overall project health in the early phases of the construction projects, are selected from the literature. Then among selected leading indicators, 10 of them are selected for defining interface health indicators. The remaining 2 health indicators, which are: (1) turnover rate in the project and (2) incomplete scope definition in the beginning of the project, are more general indicators including whole project participants. Therefore, these two indicators are excluded from interface health calculation.

The selected 10 leading project health indicators are used as a guide to create 14 interface health indicators that can be measured by automated project system data. In Table 1, the defined interface health indicators and data resource are presented.

Table 1 Interface Health Indicators

No	Description	Data Source
I_1	Number of RFIs	Request For Information System
I_2	Average response duration of RFIs	
I_3	Percentage of RFIs that have time-overruns	
I_4	Amount of Change requests	Change Management System
I_5	Percentage of cost effect of the change requests/scope changes	Interface Management System
I_6	Average response duration of change requests	
I_7	Average approval duration of the change requests	
I_8	Average number of revisions on the documents	Document Management System
I_9	Number of rejections	Interface Management System
I_{10}	Total design rework hours	Schedule
I_{11}	Design rework hours vs targeted design hours	
I_{12}	Cost effect (percentage) of design rework hours	
I_{13}	Number of milestones that are missed	
I_{14}	Delay effect on actual vs planned schedule	

In order to measure the interface health condition between project stakeholders with these indicators, both benchmark values and weights of the indicators need to be specified. The total of the indicator weights should be equal to 1. However, these values would be project specific and should be determined by the project team. Therefore, defining a general weight and benchmark table for each indicator is beyond the scope of this conference paper. For creating a functional demonstration, each indicator is accepted as equally important for the sake of simplicity.

An example interface health indicator value calculation is prepared for the third indicator, the "Percentage of RFI that has time overrun (I_3)". To calculate the value of this indicator, RFI log data (create date, need date, and completed date) between two project stakeholder needs to be collected. For a functional demonstration, RFI workflow data from a construction project of cabin gas plants in British Columbia is used. For fifteen RFI workflow instances, log data between two stakeholders can be seen in Table 2. The last two columns of the table show the duration of the workflow instances and the difference between need and closed date (time overrun).

Table 2 RFI workflow log data between two project stakeholders

Create date	Need date	Closed date	Duration (days)	Time overrun (days)
8/11/2010	8/11/2010	8/13/2010	2.00	2.00
8/11/2010	8/11/2010	8/12/2010	1.00	1.00
8/20/2010	8/24/2010	8/23/2010	3.00	none
8/11/2010	8/12/2010	8/12/2010	1.00	none
8/11/2010	8/12/2010	8/12/2010	1.00	none
8/11/2010	8/12/2010	8/16/2010	5.00	4.00
8/11/2010	8/16/2010	8/12/2010	1.00	none
8/11/2010	8/17/2010	8/17/2010	6.00	none
8/11/2010	8/12/2010	8/13/2010	2.00	1.00
8/18/2010	8/24/2010	8/20/2010	2.00	none
8/18/2010	8/24/2010	8/23/2010	5.00	none
8/18/2010	8/24/2010	8/18/2010	0.00	none
8/18/2010	8/24/2010	8/20/2010	2.00	none
8/18/2010	8/20/2010	8/20/2010	2.00	none
8/26/2010	8/26/2010	8/27/2010	1.00	1.00

In this sample data, the average duration of the RFI workflow instances is calculated as 2.27 days, and 33% of the workflow instances have time overruns. Also, the average duration of time overruns is calculated as 0.6 days. After calculating these values, a benchmark table that shows the indicator value according to these calculations would be used. An example benchmark table for RFI time overrun values between two stakeholders is presented in Table 3. It is worth repeating; these benchmark tables would be project specific, and the project team should define the values according to project goals and expectations.

Table 3 Example benchmark table for RFI time overrun

Time overrun (%)	Indicator value
0.0% - 20%	1.0
21% - 40%	0.7
41% - 60%	0.5
61 % - 80 %	0.3
81 % -100 %	0.1

According to the example benchmark values in Table 3, the value of the mentioned interface health indicator (I_3) would be 0.7. In this conference paper, all of the interface health indicators defined have a negative indicator nature. As in this example calculation, when the percentage of time overruns gets higher between two stakeholders, the indicator value of I_3 would get lower due to its negative indicator nature.

The remaining 13 interface health indicators can be calculated by following similar steps. After calculating each indicator value between two project stakeholders, Equation 3 can be used to calculate interface health

value between those stakeholders. In this equation, “w” represents the weight of each criterion, and “I” represents calculated values of each interface health indicator.

[3] $\mathrm{H} = (\mathrm{w}_1\mathrm{xI}_1) + (w_2\mathrm{x}I_2) + (w_3\mathrm{x}I_3) + (w_4\mathrm{x}I_4) + (w_5\mathrm{x}I_5) + \cdots + (w_{14}\mathrm{x}I_{14})$

Interface health (H) value between two stakeholders varies between 1 and 0, where higher value would mean better project health. After calculating the H value between two stakeholders, interface health condition can be determined by using a final benchmark table that is defined by the project team. After defining interface health condition of each connection between project stakeholders, these results can be presented on the network system explained in the preceding sections.

For the project presented in Figure 2 previously, an example H value table that summarizes interface health values between project stakeholders is given in Table 4 below. For this example, interface health condition for H values between “0.8” and “1” are accepted as “Good Interface Health”, while the values between “0.5” and “0.79” are accepted as “Average Interface Health”, and the values below “0.5” are accepted as “Poor Interface Health”. According to these benchmark values, interface health condition between these eight project stakeholders are presented on the network by using color-codes in Figure 4.

As it is explained in Section 2.1, interface health between two stakeholders is bidirectional, and each stakeholder might experience health of the relationship differently. In this example project, both the pair of Stakeholder A and Stakeholder B, and Stakeholder Y and Stakeholder N experienced health of their relationships differently. In such case, on the overall network representation of the interface health condition, the color of the link between those stakeholders would be the associated color of the lower H value calculated. However, knowing each H value and seeing the actual colors of the links as it is shown in the lookouts in Figure 4, would help upper-level managers to diagnose any health problem that arises from those connections.

Table 4 Example Interface Health (H) Values between project stakeholders shown on Figure 3

Name	Value	Name	Value	Name	Value	Name	Value
H_{AB}	0.46	H_{NX}	0.85	H_{YN}	0.82	H_{LM}	0.88
H_{BA}	0.82	H_{XY}	0.80	H_{NY}	0.76	H_{NK}	0.86
H_{AX}	0.40	H_{YX}	0.88	H_{NM}	0.86	H_{KN}	0.81
H_{XA}	0.42	H_{XM}	0.65	H_{MN}	0.83	H_{BL}	0.92
H_{AN}	0.65	H_{MX}	0.72	H_{NL}	0.84	H_{LB}	0.89
H_{NA}	0.72	H_{BN}	0.40	H_{LN}	0.81		
H_{XN}	0.82	H_{NB}	0.42	H_{ML}	0.90		

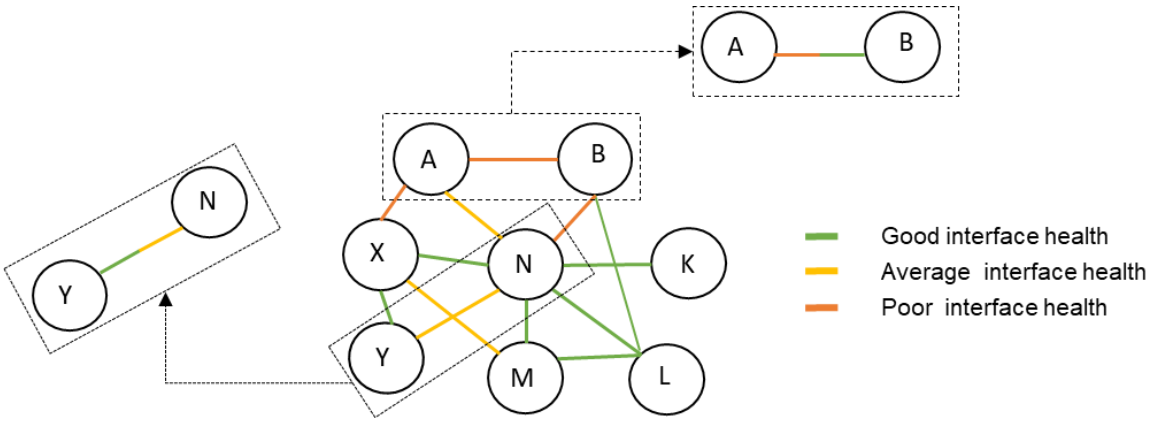

Figure 4 Interface health condition presentation on the network system

These network representations of interface health condition between project stakeholders can be used as a dashboard for upper-level managers in complex construction projects. Diagnosing any interface health

problem between project stakeholders before it affects overall project health can be achieved by using the explained model.

5 DISCUSSION AND FUTURE WORK

In this conference paper, a model for measuring interface health between project stakeholders in complex construction projects during their design phase is explained. In the presented model, interface health measurements are done with the indicators that would have quantitative data available in the project management systems that are used. Future work of this research includes: (1) indicators that would require qualitative data acquisition are being combined in this research to derive more detailed project health calculation results, and (2) interface health indicators that can be used in the other phases of the project lifecycle are being added to the model.

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