The Evolution of Network Structure and Media Choice in Operational Emergency Swift Teams: An Exploratory Study

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Abstract
This study looks at swift teams formed with the purpose of recovering from operational emergencies. The problem solving process associated with these teams include an early stage, where the main goal is to restore the process to working conditions, and a later stage, longer in duration, where the root cause of the problem is found and eliminated. Based on field data from 19 swift teams at an industrial operation, it was found that in the evolution from early to later stage, media usage shifts from highly synchronous to asynchronous and the structural characteristics of the teams’ collaboration networks mutate as well. These effects are different when comparing high vs. low performing teams.

1. Introduction

An operational emergency (OE) is here defined as an unexpected event that seriously disrupts or even stops the normal operation of the value-adding process by which products or services are created. Examples of OEs are power outages, system down times, production stoppages due to machine breakdowns or the need to interrupt work due to unsafe working conditions.

Obviously, once an OE is detected, restoring the process is a high priority. To do so, in many cases ad-hoc teams are formed which are tasked with restarting the operation as soon as safely possible.

These teams are in many occasions formed by resources that happen to be available at the moment of the OE and as such their membership is unpredictable. As a result, these teams in many cases have no, or very little, prior experience working together and they may have members with varying and unforeseen degrees of formal authority, training and skills.

These teams configure an example of ad-hoc teams called herein swift teams (STs). Going along with recent [1, 2] research we are going to call swift teams those that “are ad-hoc teams formed for immediate performance” [2].

Several are the special challenges that swift teams face when compared to more traditional and relatively more permanent ones, and these challenges are exacerbated when the task at hand involves a substantial stress to attain immediate success. They do not have a pre-planned problem solving strategy or leadership, they need to mobilize other internal and external resources quickly, they have to deal with imminent deadlines, they need to self-organize, assigning people to roles on the fly and they need to quickly assess the level of competency of the different members for an efficient task distribution.

A particular trait makes the study of OE problem solving especially interesting: many times OEs are dealt with in two steps or stages.

In the first step the goal is to rapidly restore the functionality of the system, warranting the minimum and most efficient level of analysis required to quickly come up with a workable solution that will restore the process. These temporary solutions normally meet few, yet important, thresholds such as minimum standards of safety, quality and reliability.

In a second step, of normally much longer duration than the first, the team seeks to carefully find and solve the underlying causes of the problem in order to develop a cost-effective, permanent solution that will help prevent the OE from happening again in the future. The process mirrors for instance what we observe when paramedics tend to the victim of an accident: First responders seek to stabilize the patient while later they and other health professionals investigate and treat the underlying causes of distress.

This two-stage problem solving process, with different priorities and different time constraints has
to our knowledge not been addressed simultaneously in previous research, which is attempted in this paper. The broader subject of this manuscript is exploring some of the factors that make OE swift teams successful influence both the early and late stages of OE problem solving. Of those factors, we focus on the shape of the teams’ collaboration network, and on the type of media they choose to collaborate in each stage.

The swift teams’ collaboration networks represent how members interact to perform tasks. Different interaction patterns may include whether collaboration is centralized in one or few members of the team or on the contrary it is decentralized and shared evenly, or whether a subgroup of members seem to channel and relay communication more than others.

Given the different foci of attention in the two-step problem solving effort, where in the first step the goal is to rapidly restore operational conditions and in the second the goal is to find and root out the cause of the problem, a first research question that is going to be addressed is: Do swift team collaboration network patterns change from the short term to the longer term?

Also, collaboration is facilitated in swift teams by different media, such as face to face contact, e-mail, phone conversations and written correspondence. A second research question is: Is there a shift in media choice vis-à-vis the evolution from short to long term?

Finally, we are interested in finding whether the network characteristics influence the team’s overall success. A number of studies supported that network traits impact success metrics in teams working in different environments. The third research question is then: Are specific collaboration network traits related to the success of OE swift teams?

We attempt to explore these questions using field data on swift teams that assemble to restore the operational availability of different production lines in a manufacturing setting, and who collaborate using a range of different media.

2. Literature review and exploratory hypotheses

While ad-hoc teams have not received the same level of academic attention as their more traditional counterparts, they are growing in importance [2] and number of studies have looked at them under different names such as action teams [3] impromptu teams [4], swift starting teams [5], short term teams, [6] “cheetah” teams [7, 8] or the name used here: swift teams [1].

Swift teams face a number of particular operational challenges when compared to traditional, established teams. First, the former usually have a low level of familiarity since their membership is determined more or less randomly, for instance depending on who is on duty at the time of the team’s assembly, and/or the circumstance of the emergency they need to attend to. Second, they are under extreme time constraints, having to produce results in very short time spans. Third, they are constrained in terms of resources available that might not be the ones strictly necessary, requiring some degree of improvisation. Fourth, these teams are heavily performance driven, rather than process or relationship oriented [2].

Swift teams have been explored in different settings, from healthcare [9] to flight crews [2], to new product development [8] just to mention a few examples.

A natural question receiving significant attention in previous research is what factors make swift teams relatively more successful.

Factors for swift team success include the development of “swift trust” based on the team members’ individual propensity to trust as well on their assessment of the others in terms of their belonging to previously evaluated categories [10]. This swift trust, however, seems to be short-lived [11] and in successful teams is replaced with knowledge-based trust after some familiarity has been established.

Other factors potentially linked to swift team success include member diversity and , familiarity [1]. Performance in swift teams has been measured by self-assessment or by the subjective external evaluation of the team’s performance [1].

Media choice in teams is a success factor established in the literature [12, 13] and as such has been explored in the light of different theories such as media richness [14], media synchronicity [15, 16] or the theory of media affordances [17].

In this paper we look at media choice from two points of view: Donabedian’s social influence model [18] and media synchronicity theory [15, 16].

Under the social influence model, media choice will be influenced by two factors: the level of decision ambiguity and the potential benefits of the chosen media for group coordination.

The early stage of OE problem solving is strongly influenced by the need of rapid coordination with a very clear goal in mind: restoring operational functionality. In this stage, decisional ambiguity is low and the team’s goals are perfectly defined.
Also, the need for coordination is very high, and there is a big incentive to select whatever media type that offers the most expected benefits from the coordination standpoint. The team does not have any significant slack times and they need to make sure that most of their actions are value-added and coordination costs are kept low.

These considerations of low decisional ambiguity and high expected benefits from coordination will, following Donabedian [18], imply that the optimal alternative in terms of media choice is the group-rational choice where the group collectively and rapidly survey media options and reduce the possibilities to a small admissible set of alternatives compatible with the high coordination needs of the team.

From here, we can expect that in the first stage of OE solving the teams will collectively converge on one or a narrow set of media, and that the media chosen will be such as to offer a high degree of coordination capabilities.

From the point of view of media synchronicity [16], highly synchronous media should be preferred when performance is time dependent, since high synchronicity media such as face to face contact, real time telephone conversations and such provides a high level of parallelism making possible to reach several message recipients at once without delays, which is compatible with low coordination costs. Then, we can expect that:

**H1: Media with higher degree of synchronicity will be chosen for the earlier stage of OE problem solving**

Figuring out what kind of networked collaboration structure distinguishes successful swift teams is a direct response to a recent call to address the need to “…study the interaction of diverse swift teams and its impact on problem solving” [1].

Team structure has been previously studied using social network analysis tools and metrics [19]. The theory behind social network analysis [20] sees features of social actors as the result of the actors' embeddedness in one or more networks. In these networks, actors are nodes and ties are present when there is a specified relationship between two actors [19]. In this particular case, actors are the swift team members and there is a link if they communicated about the OE.

Graph theory provides a way to characterize and differentiate particular networks. There are actor-level parameters such as actor degree or actor centrality, and also network level parameters such as network density or network centralization [19].

Previous literature on established traditional and virtual teams indicates that the association between network traits and team success is possibly context-dependent and varies in accordance to how success is defined.

In a new product development setting, network density was positively associated with performance [21], but other researchers argued for an inverse relationship or even an inverse-U shaped relationship [22, 23].

In a study of software projects network density has been negatively associated with task quality but positively associated with team productivity, whereas degree centralization was positively associated with both [24].

No studies to our knowledge have explicitly investigated the collaboration network characteristics of swift teams. In a tangentially related work, successful swift teams have been found to have more stable interaction patterns in terms of duration, complexity and reciprocity, where interaction patterns have been defined as sequences of verbal cues such as “question-answer” or “command-question-command” [2] but not as traditionally used network parameters such as density or centralization. A key finding from this study is that initial interactions “set the tone” of the team dynamics that are ultimately related to team performance.

However, as mentioned before, no study has examined a two-stage OE problem solving process, and although for this exploratory study, the direction of association is not going to be argued, it is going to be posited that since in the early stages of OE solving the time pressures create a bigger need of immediate coordination, the network effects on performance are going to be more pronounced than in the later stage of OE problem solving. Since density is related to the degree of parallelism in communications, and centralization is related to the existence of relatively more important "information brokers”, it stands to reason that density should be higher in the stage that requires higher parallelism, i.e. the early stage, and centralization should conversely be higher in the stage that requires making sense of diverse views and solution alternatives, which is the later stage. Then following hypotheses are going to be stated:

**H2: Density is more strongly associated with team performance in the early stage of swift team problem solving**

**H3: Centralization is more strongly associated with team performance in the late stage of swift team problem solving**
3. Methods

3.1. Research background

The empirical exploratory tests were conducted with field data retrieved at a medium-sized industrial company located in Argentina. The company produces composite material tubing and seam-welded steel tubing for use in the country’s oil and gas industry.

Of the several business units of the firm, the one selected for this study is the one producing Electric Resistance Welded (ERW) cylindrical steel tubing in diameters ranging from 4” to 16”. This unit was selected because as per its maintenance records it would be relatively more prone to operational stoppages than other units and then offer a richer environment for collecting data. The ERW unit hosted about 230 direct workers, including production, maintenance, quality control and indirect areas. Most areas of the business unit worked in two shifts, and the unit’s annual sales were in 2013 in excess of USD 50 million.

The production process for ERW tubing involves cutting a roll of cold-laminated steel into strips of a size depending on the diameter and thickness of the tube to be produced, and then gradually longitudinally bending the strip of metal inwards until a tube was created and the longitudinal opening was arc-welded by means of a low voltage, high current electricity.

The finished tube is then cut to measure, threaded, fitted with accessories if required and tested before being dispatched to the oil fields.

Production lines used to build tubes of different diameters and thicknesses are fairly large and complex, and have multiple adjustment points that need to be customized for the specific combination of material, thickness and diameter to be processed. The machines were in average 20 years old, retrofitted with modern electronics and software control panels and as in any other complex operation it presented occasional stoppages due to mechanical or electrical/electronic issues, raw material problems or due to other unforeseen circumstances such as software bugs in the control system.

A production line stoppage is normally signaled by the line physically stopping and visual and / or auditory alarms. When such alarms go off, usually the production supervisor goes to the point of the line where the stoppage occurred and summons by two-way radio an available maintenance worker or supervisor and other personnel as needed in order to restart production as soon as possible, assembling an ad-hoc team for the first time.

The swift team created on the spot will have members who not necessarily have familiarity working together, since the composition depends on who is available in the particular shift (shifts rotate every other week), and the kind of problem in principle detected, whether it is believed to be mechanical, electrical, electronic, software-based, health and safety related, or other kinds of issues.

Following the precepts of Total Productive Maintenance [25], under which the company operates, the team works first on an immediate countermeasure to safely restart production as soon as possible, and later the same members communicate using different kinds of media to investigate, find and remove the root cause of the stoppage to make sure that the same kind of problem will not happen again in the future.

While in the first stage communication is basically face to face, in the second stage collaboration also includes different kinds of media such as face-to-face, telephone, e-mail, two-way radio and written memos.

3.2. Data Collection and Sampling

With permission from the company, an employee of the firm was named as a research assistant (RA) with the purpose of helping with data collection. The RA received basic training on the data collection procedure expected from him and was coached by the author in the occasion of two OEs that presented themselves randomly during the initial training day.

When the data collection period started, during May and June 2014, all production supervisors were instructed to always call the RA using their two-way radios when an OE happened so that he could collect research data. When the RA went to the point of the production line where the alarm was triggered, he recorded all interactions (who communicated with whom) and the composition of the team, until the production was restarted. In this way, a valued graph showing the communication network could be built by the RA and network characteristics calculated later. Before the team disbanded from the initial meeting the RA collected demographics and other control variables.

The recording of further contacts among team members was left to the participants themselves. In a special notebook provided by the RA, members of the swift team recorded: person in the swift team with whom they communicated about the particular OE, communication media, and length of communication.

The first week was reserved for a test run of the data collection dynamics and due to constraints on the availability of the RA and to not overburden operators, it was decided that the RA would be called...
only if the OE was likely to last for more than 30 minutes. Other minor modifications were made to the data collection protocol and documents to make them more user friendly for the team members. During the following two months of observation, 75 OEs were reported, of which the RA was able to follow 43 due to work schedule constraints. Of those, a further 24 OE reports were deemed unusable because of inconsistencies or severely incomplete information, yielding 19 usable data sets for this exploratory study.

3.3. Measurement

While the first meeting of the swift team took place, the RA took all relational data about interactions among the team members, demographics and other perceptual data. These data were complemented with communication information up to 24 hours after the original time of the incident, configuring the data for what is called the “early stage”. Communication data for days two through seven were compiled in to the set for the “later stage”. In the last data collection instance also perceptual measurements of team success were collected.


Among the commonly used network characteristics to describe team structure are network density and network centralization.

Network density is the ratio between the number of ties present and the maximum possible number of such ties, and represents the overall collaboration intensity; zero density corresponds to a graph where all actors are isolates (team members do not collaborate), while density of one corresponds to a team where everyone collaborates with everyone else.

Actors in a network have different relative importance, i.e. centrality. Actor centrality indexes are calculated considering a certain definition of importance, for instance the number of ties they maintain, or "degree". In communication based networks, the concept of betweenness captures how much there are “information brokers” who mediate between two other team members. The strict definition of betweenness centralization is the proportion of shortest paths between any pair of other team members that go through the focal team member. For the team level metric we used the average of the normalized, actor level betweenness centralization [19].

3.3.2. Media choice

Every time there was a communication with other team members they were asked to mark in their check sheets whether they used face to face contact, two-way radio, telephone, text message, e-mail or hard copy notes. Other types of media were discarded because their proportion was irrelevant (e.g. instant messengers).

3.3.1. Team performance.

During the last day of data collection for each OE, each member of the team assessed their perception of the team’s performance using a 5-point Likert scale where 1=clearly unsuccessful and 5= clearly successful. The member average value was used as performance metric.

3.3.4. Control variables.

Familiarity with the other team members was measured right after the initial team meeting as the team average for the question: How familiar are you with working with these other team members? Where 1=very unfamiliar and 5=very familiar.

Team functional diversity was, in accordance with previous research [1], measured using Blau’s diversity index [26], where $D = 1 - \sum p_i^2$, where $D$ is the diversity index, and $p_i$ is the proportion of team members belonging to category “$i$” of $n$ possible categories. Categories here were three: 1=production, 2= maintenance, 3= other (for instance quality control or materials handling).

Face to face contact, two-way radio and telephone communications were coded as synchronous media, whereas e-mail, text message and written memos were counted as asynchronous communications.

Additionally, and after feedback from the pilot testing of the data collection protocol, the team as a whole was asked by the RA during the initial meeting if they would have liked to have additional members from other areas present that perhaps were unavailable at the time the OE happened.

Demographics of the team members included age, and years of tenure in the company. The sample was 100% male and as such gender was not included as control factor.

Trust with the other team members was measured on a 5-point scale where 1=Strongly distrust; 5=Strongly trust. Initially perceived difficulty of solving the problem was assessed after the initial meeting on a 1 to 5 scale where 1= perceived as very easy and 5=perceived as very difficult.

4. Results

Table 1 shows the average network parameters and media choice percentages measured in the two instances. A t-test was conducted to discover significant differences between groups in terms of structural parameters:
Table 1: High vs. Low Performance

<table>
<thead>
<tr>
<th></th>
<th>High performance teams (N=9)</th>
<th></th>
<th>Low performance teams (N=10)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Early stage</td>
<td>Late stage</td>
<td></td>
</tr>
<tr>
<td>Density</td>
<td>.37 22</td>
<td>8.65 p&lt;0.01</td>
<td>.26 24</td>
</tr>
<tr>
<td>Betweenness</td>
<td>.15 28</td>
<td>-9.22 p&lt;0.01</td>
<td>.18 19</td>
</tr>
<tr>
<td>Synchronous media %</td>
<td>92 76</td>
<td>13.47 p&lt;0.01</td>
<td>90 58</td>
</tr>
<tr>
<td>Asynchronous media %</td>
<td>8 24</td>
<td></td>
<td>10 42</td>
</tr>
</tbody>
</table>

As expected, the use of synchronous media was higher in the early stage of OE solving, for both groups of teams, and the more successful teams presented a bigger difference between the two stages, yielding support for H1.

Network density decreased from early to later stage, for both groups, and magnitude of the reduction was bigger in the higher performing teams, supporting H2.

Betweenness centralization increased from early to later stage, and the magnitude of the increase was bigger in the higher performing teams, supporting H3.

Table 2 shows the results of an OLS regression model where the dependent variable was self-assessed team performance.

Table 2: Regression

<table>
<thead>
<tr>
<th></th>
<th>Early</th>
<th>Later</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coeff.</td>
<td>Sig</td>
</tr>
<tr>
<td>Constant</td>
<td>0.524</td>
<td>0.814</td>
</tr>
<tr>
<td>Density</td>
<td>0.365</td>
<td>*</td>
</tr>
<tr>
<td>Betweenness</td>
<td>0.095</td>
<td>***</td>
</tr>
<tr>
<td>Familiarity</td>
<td>0.894</td>
<td>**</td>
</tr>
<tr>
<td>Functional diversity</td>
<td>0.103</td>
<td></td>
</tr>
<tr>
<td>Average age</td>
<td>0.004</td>
<td></td>
</tr>
<tr>
<td>Average tenure</td>
<td>0.054</td>
<td></td>
</tr>
<tr>
<td>Trust level</td>
<td>0.441</td>
<td>*</td>
</tr>
<tr>
<td>Task difficulty</td>
<td>-3.864</td>
<td>***</td>
</tr>
</tbody>
</table>

N=19 F=32 *** N=19 F=28 ***

R² = 0.15 R² = 0.12

H1, H2, and H3 were supported as network characteristics were associated with performance, and control variables. Functional diversity, trust, and task difficulty were also associated with performance. Interestingly, network density was only associated with performance in the early stage, while centralization was associated with performance in the later stage.

The relatively bigger importance of network density in the early stage of OE solving can be an indicator that when the swift team is highly constrained for time, it needs to bring out every possible bit of knowledge from team members, given that it would be impractical to reach out outside of the team to resources that may not be immediately available or that would require a relatively higher coordination cost, for instance investing substantial time in order to explain all the details of the emergency to external actors so that they can help. Being constrained to use skills and knowledge from within the team, all or most members need to chip in, which is evidenced by the high levels of network density observed in the early stage.

On the contrary, betweenness centralization increases in the late stage. This supports that in a
more reflective stage of problem solving there must be one or few more central actors that channel the communications from actors with diverse skill sets.

A more reflective problem solving stage requires bouncing potential solutions or ideas back and forth, and allows members to fall back to their respective specializations. It was actually noted that the more central actors were in fact members with higher formal ranking, which indicated that formal leadership is more salient in the later stage of OE solving.

Functional diversity was associated with performance only in the later stage. This could be explained because in the early stage, members have to become a sort of “jack of all trades” and do what is necessary to restore the process even if the work is outside of their formal skill set. In a later stage, swift team members may revert to their original training, being more selective in their actions.

The beneficial effect of trust and familiarity was also supported. Fostering both might not be unfeasible for managers. Perhaps team building exercises could “prime” the swift trust and offer some degree of familiarity required for better performance in swift teams.

Not unexpectedly, problems that were perceived as more difficult were associated with lower performance.

Besides the obvious limitations in terms of the small sample, which limits generalizability and some perceptual measures such as the ones for performance and task difficulty, several other limitations should be addressed in future work. A factor that was not foreseen was attrition in the teams, as well as membership change. Sometimes team members that had attended the first stage of problem solving had to drop membership in the team being replaced by another team member -in general with the same functional specialization- but some times the size of the team actually decreased over time. This brings up the need to use normalized network metrics, to make them independent of network size. Also, the shift-based nature of industrial work might have biased the needs for asynchronous media, especially in the longer term; an effect that should be compensated for in future analyses.

This work will be extended in future research: Work is under way to expand the model and collect more data over a longer time period with a refined measurement instrument, a strengthened theoretical foundation and more resources in the field.

6. References


12. Rice, R.E. and D.E. Shook, Relationship of Job Categories and Organizational Levels to Use Communication Channels, Including Electronic E-


