

# Team size effect on teamwork productivity using information technology (in particular productive organizations)

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## **Abstract**

Teams are defined as high performing task groups whose members are actively interdependent and share common performance objectives. This definition suggests that only those groups who perform at high levels due to their collective efforts must be considered as teams. In this paper, a model has been presented for determining the effects of information technology in the output of teamwork with Y structure for particular productive organizations.

**Keywords:** Teamwork; Performance; Information technology; Team size

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## **1. Introduction**

In today's complex and competitive economy, organizational outcomes are increasingly dependent on fast, effective and creative teamwork.

The empirical evidence regarding team effectiveness is limited and often has the form of anecdotes or descriptive case studies: stories of huge cost saving and quality improvement [9, 17, 12, 4, 2, 7].

Many studies have indicated that variations in team performance can be explained by differences in team structure [3, 10, 13, 16, 19].

Tranfield and Smith [18] examined, in depth, the form of team working which takes in a number of teamworking organizations across the study to ascertain their similarities and differences.

The performance in team-based working also largely depends on the employee's authorities and function design [6]; i.e. to which extent the planning, performing and controlling responsibilities integrated in the team tasks. Delarue, Gryp and Van Hootehem [5] investigated the impact of specific structure team types on the performance of the organization, measured by labor productivity.

When a new project starts, one of the most difficult

tasks is to choose the most suitable members of the work team. The most relevant factors may be grouped into three categories: I) Individual characteristics; II) Social characteristics; III) Temporal and economic costs [1].

Advances in information technology have enabled new organizational forms and new ways to structuring work. In the age of the knowledge economy, most tasks accomplished as part of one's job require some forms of communications [14].

For long, researchers have investigated organizational communications, both formal and informal. Yet, we still need to understand better how communication-based tasks can be better supported to lead to efficiencies in an environment where individuals are distributed. Regardless of specific type of work environment, individuals must manage multiple relationships to work productively [14].

Team enables a company to execute quick changes and allows the company to be flexible [15]. Each member of a group adds more information, perspective, experience and competencies [8].

Even organizations that are better served by a team model face disadvantages. These include an increase in time to communicate, poor communication be-

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tween members and groups, poor coordination between group members and competing objectives [20].

This paper is organized as follows:

The researchers explain the assumptions of the proposed model in section 2. Section 3 introduces the parameters, used in the model. Section 4 presents a model that can be used to determine the value of teamwork performance versus information technology and team size factors. Section 5 includes a sensitivity analysis to the model, based on information technology, and section six summarizes the contribution of the paper.

## 2. The model assumptions

Although the model can be used for any team structure (with any divisions), in our proposed model we assume, there is a particular assembly line (figure 1). Also it is assumed, teamwork size is  $n$  and divided in 4 parts: I) Assembly line 1; with  $(\frac{n-1}{3})$  members (group 1), II) assembly line 2, 3; each one with  $(\frac{n-1}{3})$  members (group 2) and III) one supervisor for all above assembly lines' members.

Each assembly line has full information interactions between members separately and all members have information interactions with the supervisor.

### 2.1. General assumptions

- An individual divides his/her time between production and information processing.
- If one unit is exclusively devoted to production, exactly one unit of output is generated.
- For each unit of output, there is also a unit of

information generated.

- Each individual has to process all information received from the other team members in order to coordinate the team task.
- It takes less than one time unit to process one unit of information.

## 3. Parameters used in the considered model

$n$  : The number of team members. Also,  $n \geq 4$  and  $(n-1)$  is multiplier of 3.

$\alpha$  : The fraction of a time unit it takes to process a unit of information provided by other team members about their production. Also,  $0 < \alpha < 1$ .

$\Omega(n)$  : The fraction of time an individual can spend on production after processing the information received from the other members.

$P(n)$  : The output of team (quantity of production).

## 4. The model

It is assumed that all received information must be processed, so the processing of information during one time period can be computed as follows:

(I) For each assembly line:

$$\alpha \Omega_1(n) \left(\frac{n-1}{3}\right) \text{ units of each individual's time} \quad (1)$$

(II) For supervisor:

$$\alpha \Omega_2(n)(n-1) \text{ unit of individual's time} \quad (2)$$

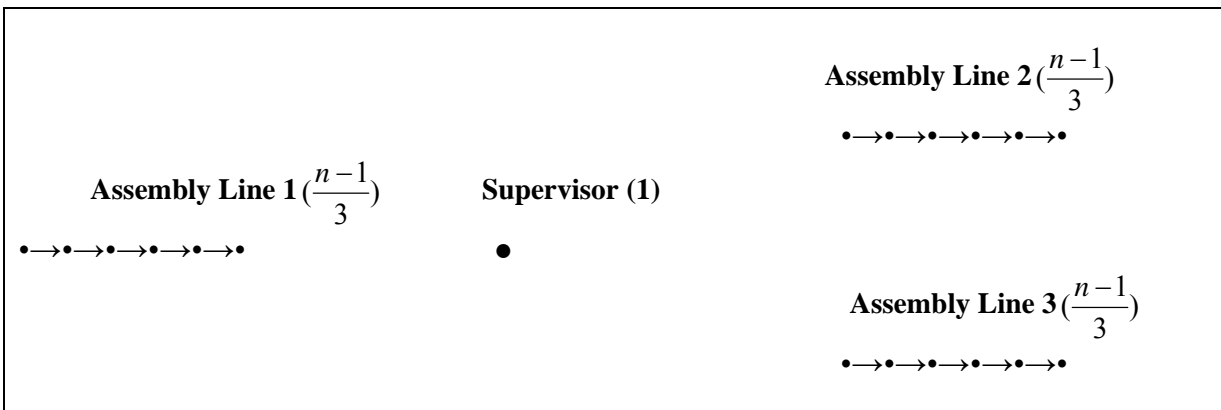


Figure 1. An assembly line with Y structure.

The remaining fraction of the time period which can be spent on production, is given by:

For each assembly line:

$$\Omega_1(n) = 1 - \alpha \Omega_1(n) \left( \frac{n-1}{3} \right) \quad (3)$$

$$\Omega_1(n) = \frac{1}{1 + \alpha \left( \frac{n-1}{3} \right)} \quad (4)$$

For supervisor:

$$\Omega_2(n) = 1 - \alpha \Omega_2(n)(n-1) \quad (5)$$

$$\Omega_2(n) = \frac{1}{1 + \alpha(n-1)} \quad (6)$$

So equations (1) and (2) are equilibrium conditions on information generation and information processing. As the size of team increases, each individual will spend a larger proportion of his/her time processing information provided by other team members and, hence, the time left for production is reduced. In practical terms, this implies that as the team size grows, the individual team members get saturated with information and productivity drops [11].

The total production of the team during one time period is then:

$$P(n) = (n-1)\Omega_1 + \Omega_2 \quad (7)$$

$$P(n) = \frac{n-1}{1 + \alpha \left( \frac{n-1}{3} \right)} + \frac{1}{1 + \alpha(n-1)} \quad (8)$$

**Theorem 1.**  $P(n)$  is a concave, monotonically increasing function of  $n$  for all values of  $0 < \alpha < 1$  and  $n \geq 4$

**Proof:**

$$\frac{dP(n)}{dn} = \frac{1 + \frac{\alpha}{3}(n-1) - \frac{\alpha}{3}(n-1)}{\left[1 + \alpha \left( \frac{n-1}{3} \right)\right]^2} + \frac{-\alpha}{[1 + \alpha(n-1)]^2} \quad (9)$$

$$= \frac{1}{\left[1 + \alpha \left( \frac{n-1}{3} \right)\right]^2} - \frac{\alpha}{[1 + \alpha(n-1)]^2} > 0, 0 < \alpha < 1 \quad (10)$$

$$\frac{d^2P(n)}{dn^2} = \frac{\frac{-\alpha}{3}}{\left[1 + \alpha \left( \frac{n-1}{3} \right)\right]^3} + \frac{2\alpha^2}{[1 + \alpha(n-1)]^3} < 0, 0 < \alpha < 1 \text{ and } n \geq 4 \quad (11)$$

Hence,  $P(n)$  is a concave, monotonically increasing function in  $n$ .

Theorem 1 indicates that team output can be increased by adding members to the team. However, the marginal product of team members is decreasing due to the increased coordination effort required so that for each added team member, there is a smaller and smaller increase in output. Beyond some value of  $n$ , the marginal cost of an additional team member exceeds the marginal value of the team's production.

**Theorem 2.** For any non zero  $\alpha$ ,  $P(n)$  is a bounded function.

**Proof.** From theorem 1,  $P(n)$  is a concave and monotonically increasing function of  $n$ . Also,  $P(0) = 0$ .

$$\lim_{n \rightarrow \infty} P(n) = \lim_{n \rightarrow \infty} \frac{n-1}{1 + \alpha \left( \frac{n-1}{3} \right)} + \frac{1}{1 + \alpha(n-1)} = \frac{3}{\alpha} \quad (12)$$

Hence,  $P(n)$  is a bounded function.

The practical implication of theorem 2 is that the maximum total production of a team during one time period depends on the speed at which the team members can coordinate their activities with their peers.

To increase the team's maximum production capacity, it is necessary to change the communication and processing technology (i.e. decrease the value of  $\alpha$ ) or, the work has to be reorganized so that each team member does not process all of the information provided by the other members.

**Theorem 3.** The marginal product of team size is asymptotically zero.

**Proof:**

$$\lim_{n \rightarrow \infty} \frac{dP(n)}{dn} = \lim_{n \rightarrow \infty} \frac{1}{\left[1 + \alpha \left(\frac{n-1}{3}\right)\right]^2} - \frac{\alpha}{\left[1 + \alpha(n-1)\right]^2} = 0 \quad (13)$$

Theorem 1 shows that the marginal product of team size is decreasing and theorem 3 states that the marginal product of team size is asymptotically zero. These two facts imply that for a one-period production effort, there is a single optimal team size if the cost per team member is positive and marginally non-decreasing. This condition is equivalent to the well-known profit maximum condition that marginal cost equals marginal revenue in economic theory.

## 5. Sensitivity analysis

Now, the effect of changing information technology on team output is studied. An improvement in information technology implies that the time it takes to communicate and process a unit of information is reduced. Thus, as information technology improves the parameter  $\alpha$  decreases.

Although information technology improvements are likely to occur in discrete increments, it is useful to study the first order derivative of the total team output.

**Theorem 4.**  $P(n, \alpha)$  is monotonically decreasing function of  $\alpha$  for all values of  $0 < \alpha < 1$ .

**Proof:**

$$\frac{\partial P(n, \alpha)}{\partial \alpha} = \frac{-(n-1)^2}{3 \left[1 + \alpha \left(\frac{n-1}{3}\right)\right]^2} + \frac{-(n-1)}{\left[1 + \alpha(n-1)\right]^2} < 0 \quad 0 < \alpha < 1 \quad (14)$$

Hence,  $P(n, \alpha)$  is monotonically decreasing in  $\alpha$ .

Thus, as information technology improves ( $\alpha$  is reduced), team output increases. This result is consistent with expectation since less time spent on infor-

mation processing implies more time spent on production.

Similarly, as information technology improves, so does the maximum output of the team. Let  $\Delta$  be the reduction in processing time of one unit of information so that  $\alpha' = \alpha(1 - \Delta)$ . Then, the increase in maximum team output is:

$$\frac{3}{\alpha'} - \frac{3}{\alpha} = \frac{3}{\alpha(1 - \Delta)} - \frac{3}{\alpha} = \frac{\Delta}{1 - \Delta} \frac{3}{\alpha} \quad (15)$$

In marginal terms, there is a trade-off between adding manpower to a team and improving the information technology support to the team.

The following example will illustrate the concept. Consider a team with 22 members and information technology which allows team members to process information at a rate of 22 units per time period (i.e.  $\alpha = 0.05$ ). According to (8) the output of this team is 16.05 per time period. If the team size is increased to 28 members it's output will be 19.05.

The same output per time period can be achieved by information technology improvement with the rate of information technology processing (i.e.  $\alpha = 0.02$ ).

If the cost of 6 new team members is higher than the cost of upgrading the information technology, then an information technology upgrade is the best decision. If there is a number of technology improvement options, there may be a combination of technology improvement and team size increase that will yield the most cost efficient solution to increase team output.

Similarly, if the demand for the organization output is fixed, the organization can achieve a productivity increase by investing on improved communication and processing technology and reducing the number of team members. If technology investments change the information processing rate (i.e.  $\alpha = 0.02$ ) in this example, the team size can be reduced to 22 members without reducing production. Thus, by investing in communication and information processing technology, labor cost can be reduced by 21.5%. Considering the significant price reduction trends in communication and information processing technology, this explains the substantial reduction in team size, often referred to as corporate downsizing, taken in modern post-industrial economies.

Figures 2 and 3 show team output per time period for various levels of information technology factor ( $\alpha$ ).

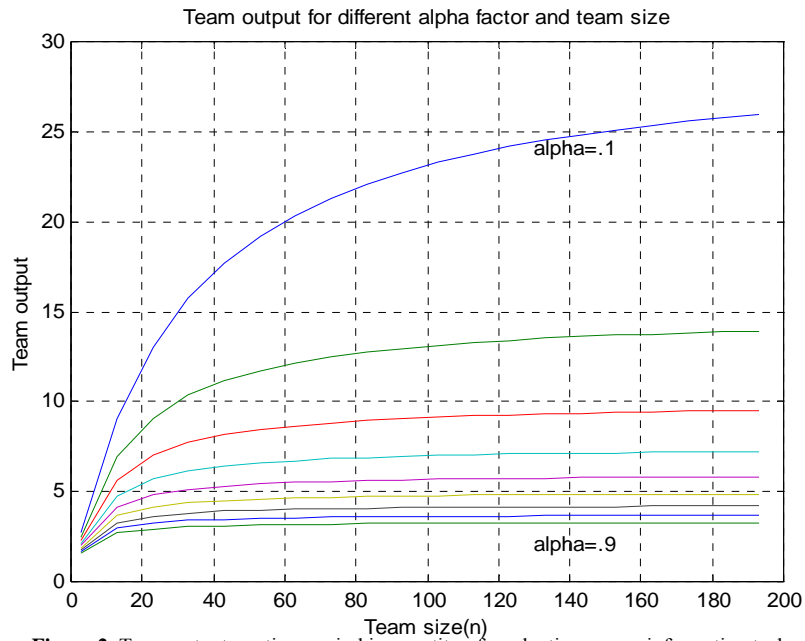
### 6. Conclusions

In this paper, a model has been presented that can be used to determine the value of teamwork performance versus information technology and team size.

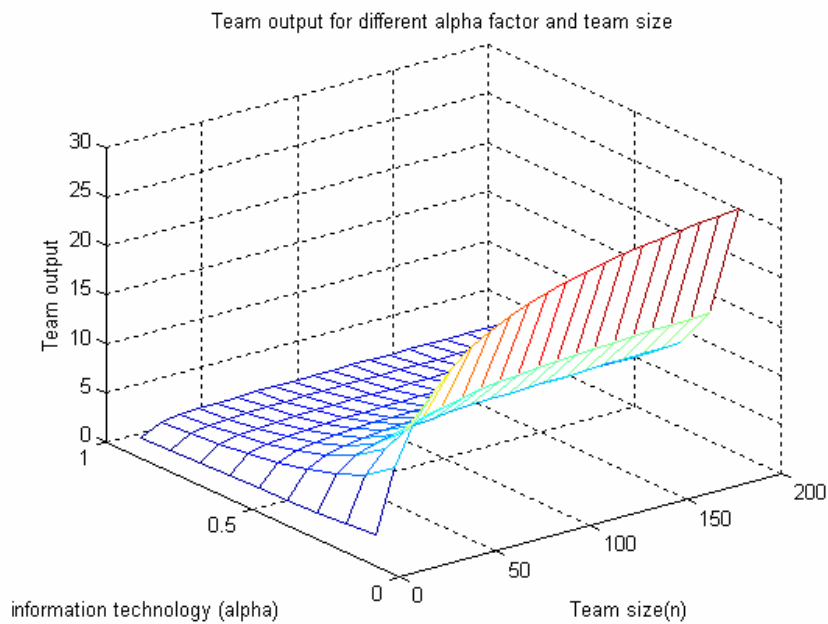
According to this model, team output can be increased by adding members to the team. But beyond some value of team size, the marginal cost of an additional team member exceeds the marginal value of

team's production. Also to increase the team's maximum production capacity, it is necessary to change the communication and processing technology. If the cost per team member is positive and marginally non-decreasing, there is a single optimal team size.

If there is a number of technology improvement options, there may be a mixture of technology improvement and team size increase that will yield the most cost efficient solution to increase team output.



**Figure 2.** Team output per time period in quantity of production versus information technology and team size.



**Figure 3.** Team output per time period in quantity of production versus information technology and team size.

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