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**Research paper**

# Analysis of the impact of communication between the participants of a construction project on its completion time and cost

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**Abstract:** Communication and information flow during construction project execution is often discussed in the literature. Numerous scholars note the presence of problems with communication and information flow and highlight that these problems also affect construction project completion time and cost. The vast majority of studies on the impact of communication on construction project completion time and cost takes on a qualitative character and there is a lack of quantitative analyses of this subject. To address these deficiencies, the authors of this paper propose a quantitative approach to assessing communication between construction project participants in the aspect of its impact on said project's completion time and cost. The authors used meta-network theory to model and analyse the problem, as it can fully depict the problem's complexity. The method proposed allows for dynamic identification of key information flow paths between project participants, which determine its performance in an essential way. The proposed approach can support decision-makers in effective management of communication between a construction project's participants, which has a positive carryover to achieving planned project goals. The method was tested on a real-world development project that featured the construction of a housing complex in Katowice, Poland.

**Keywords:** construction management, information flow, Meta-Network Analysis (MNA), optimisation

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# 1. Introduction

Along with the development of the construction industry, construction processes become an increasingly dynamic and complex form of activity and there is rising awareness of the need for better project management in this sector [1]. This partially stems from rising client demands concerning technology, performance, savings, the pace of design and construction [2]. Oftentimes, design and construction are done in parallel to speed up the project [3,4]. These changes make construction design and execution process management, i.e. the coordination of multiple teams, a serious challenge. Communication systems enable hundreds of people to perform numerous tasks and coordinate their efforts and abilities towards achieving a shared goal [5]. This is especially true in the construction sector [6]. Studies by Knoop, Breemen, Vergeest and Wiegers [7] and Thomas, Tucker and Kelly [8] confirmed the significance of communication in design and clearly indicated a positive link between success in communication and success in design in construction.

Communication and information flow in construction was discussed in numerous studies and reports [9–12]. Communication is typically based on information transfer, a term that encompasses notions like knowledge, processed data, skills and technologies [13]. In construction, information is exceptionally varied considering the immense number of parties involved in construction work. Construction is, by its very nature, a team task that is characterized by multiple participants but also requires division and coordination of work. Project participants have needs in terms of the information they require and communication. Identifying the information needs of interested parties and determining the proper means of satisfying these needs are important project success factors. We should therefore identify project participants, their needs and expectations, and then manage them.

In a cycle of publications, Radziszewska-Zielina and Szewczyk [14, 15] analysed communication as a fundamental factor in partnering relations. Construction project success parameters can be improved by, among others, improving relations and communications between parties within a construction project [16, 17]. Deficiencies in sufficient communication between project participants were identified by Radziszewska-Zielina and Kania [18] as a major cause of problems during the execution of projects in central areas of urban agglomerations. In [19], the authors once again noted difficulties in information and documentation flow as a problem that is present in the construction of buildings in urban agglomeration downtown areas.

Dainty, Moore and Murray [20] answered the question as to why it is worth studying various aspects of communication in construction and to improve its effectiveness. They noted the network-like character of construction projects. Every person involved in a project plays a role in a complex communication network. The perception of the environment of a construction project as an interlinked network is justified as all such projects, regardless of how well-defined they may be, cannot be successfully executed without interactions and transactions between people and organisations. The analysis of construction project organisation from a network standpoint has been under intense development for two decades. Social Network Analysis (SNA) was successfully used as a tool to analyse communication and information flow between project participants [21]. For instance, Ruan, Ochieng, Price and Egbu [22] used SNA to investigate the dependency of integrated knowledge transfer on the structure of links within a network. The authors of [23, 24] documented means of communication and its frequency, along with the impact of the link structure on said communication's effectiveness within specialist construction crews in the context of occupational health and safety (OHS). Sheikh and Pryke [25] presented how SNA can be used to identify gaps in communication networks. In [26], they observed that SNA application can structure information flow management during construction project execution. The contract is not a structure that supplies all information details or mediates in relations. When building network models using SNA, they noted that a more complex pattern may emerge that illustrates how information can flow or potentially not flow through a network. The authors of [27] investigated a self-organising communication network in a construction project and detected dysfunctions that appeared in it. Radziszewska-Zielina, Śladowski, Kania, Sroka and Szewczyk [28] presented an original optimisation model based on SNA along with an algorithm of its analysis, which can support construction project managers in controlling and monitoring communication between construction projects participants. Trach and Bushuyev [29] observed that communication networks are elements of knowledge management systems in projects and are used to organise and maintain information links between project participants. They analysed a network of communication between the participants of a housing development projects using Social Network Analysis (SNA), calculating and analysing centrality measures for construction project execution participants.

Despite all this, the application of SNA in the analysis of communication between project participants does not allow one to identify the direct causes that determine it, such as the impact of a project's formal organisation structure, construction work schedule and identification of knowledge assets required to complete tasks. In [30], the authors of this paper used the potential of meta-networks and data concerning: a project's formal organizational structure, task execution schedule and the participants assigned to their performance, information on the knowledge in possession of the participants, which is necessary to carry out each task, proposed an optimisation approach to planning and monitoring the necessary communication between construction project participants. This paper is a continuation of earlier studies on managing communication and information flow between construction project participants. It was observed that a clear majority of studies [31–33] on the impact of communication on construction project completion time and cost took on a qualitative character, while there was a lack of quantitative analyses. To address this deficiency, the authors of this paper proposed a quantitative approach to assessing communication between construction project participants in the aspect of its impact on project completion time and cost.

## 2. Application of the proposed approach to planning and monitoring necessary communication in terms of its impact on construction project completion time and cost

To build the dependency structure between participants, knowledge and tasks within the project under analysis, the authors used meta-networks [34].

A network set is determined, wherein every network is based on a directed graph, which consists of a set of two elements, $U$ and $V$, and a set of relations: $E \subset U \times V$. Each pair of elements $(i, j) \in E$ for $i \in U$ and $j \in V$, denotes a relation between $i$ and $j$. The set of networks that represent such relations are called meta-networks [35–37].

The network set within a meta-network can be represented by a set of matrices, whose graphical interpretation for three sample node classes: agents (interpreted as individuals or organisations), knowledge and tasks, has been presented in Table 1.

Table 1. Meta-matrix including matrices that represent six types of networks within three node classes

| **V**<br>**U** | ***A***<br>**(Agent)** | ***K***<br>**(Knowledge)** | ***T***<br>**(Task)** |
|---|---|---|---|
| ***A***<br>**(Agent)** | **(*AA*)**<br>*Who communicates with whom?* | **(*AK*)**<br>*What knowledge does a given agent have?* | **(*AT*)**<br>*Which tasks does a given agent perform?* |
| ***K***<br>**(Knowledge)** | * | **(*KK*)**<br>*What is the dependency between pieces of information?* | **(*KT*)**<br>*Which tasks can be completed with a given piece of knowledge* |
| ***T***<br>**(Task)** | * | * | **(*TT*)**<br>*What is the dependence between tasks?* |

Numerous structural measures that provide different forms of information about dependencies within networks have been formulated in the literature [38, 39]. These measures were presented in an earlier publication by the authors [30] n the context of necessary communication analysis in a construction project, alongside a proposed optimisation model.

The proposed mathematical model of optimizing necessary communication as a part of linear discrete binary programming was discussed at length in [30]. Its continuation, which enables the location of key communication links between participants, whose lack affects a given project's completion time and cost, shall be presented below.

## 2.1. Necessary communication optimisation model: module for analysing impact on construction project completion time and cost

To obtain information on which tasks featured in the work schedule could not be completed due to lack of communication and information flow between construction project participants and the consequences this would have on project completion time and cost, an analysis of the impact of the removal of successive links between each participant in an optimal communication network (presented in [30]) was performed.

Below is a presentation of the course of action in this analysis:

1. An optimal necessary communication matrix $Q$ was used, as obtained in [30] by performing a successive series of $m$ iterations whose number equals that of ones in matrix $Q$.
   a. Matrix $Qm$ was assumed, in which one link is successively removed (a matrix in which successive $m$-th ones shall be replaced with zeroes).
2. For each iteration of matrix $Q$ the following steps that allow detection of task performance delays should be followed:

2.1. Communication due to knowledge necessary to complete tasks:

a. Determination of matrix $Z$ (knowledge necessary to complete tasks) analogously to the first part of the model, using the formula below:

$$\mathbf{Z}(tk) = \begin{cases} 1, & \text{if } \ [AT' \cdot AK - KT'], \ \ (t,k) < 0 \\ 0, & \text{otherwise} \end{cases} \tag{2.1}$$

b. Successive $p$ iterations are performed, equal in number to that of ones in matrix $Z$.
   - Identifiers of tasks that shall be included in successive iterations are marked (e.g.: iteration for task $t_1$ due to knowledge $k_1$ $(Np(t_1 k_1))$.
   - Matrix $Zp$ that consists solely of a $p$-th one from matrix $Z$ is assumed.
   - Matrix $Np$ (communication necessary due to knowledge required to complete a task) is calculated from the following formula:

$$Np = AT \cdot Zp \cdot AK' \tag{2.2}$$

   - $K$ – set of numbers of $Np$ matrix rows that include non-zero values (set of agents who communicate with others as per matrix $Np$),
   - $L$ – set of column numbers of $Np$ matrix that include non-zero values (set of agents who communicate with agents defined as set $K$).

c. Matrix $Qm$ is compared with every successive $Np$ matrix obtained during successive iterations:
   - If an element of a matrix (an arch that was removed from the optimal matrix in a given iteration) $qm_{ij} = 0$ in matrix $Qm$ and element $np_{ij} = 0$ in matrix $Np$, then move to the next iteration stage.
   - If element $qm_{ij} = 0$ in matrix $Qm$, and element $np_{ij} = 1$ in matrix $Np$, then compare the remaining elements of matrix $Np$ with elements of matrix $Qm$:
     - If there is at least one pair of elements for matrix $Qm$ and matrix $Np$ i.e. element $qm_{kl} = 1$ and element $np_{kl} = 1$ then move to the next iteration stage.
     - Otherwise, indicate this element in final matrix $Q_N$ and recall and save the task with its corresponding knowledge that was used in the iteration indicated for the creation of matrix $Np$ giving it a delay value corresponding to this task as per a previously prepared $TK$ matrix (time and cost).

2.2. Communication due to cooperation within a task:

a. Matrix $C$ (communication due to cooperation within tasks) is defined using the following formula

$$C = AT \cdot AT' \tag{2.3}$$

b. We perform $r$ successive iterations, with a number equal to the number of columns (tasks) in matrix $AT$,
   - We point to identifiers of tasks that will be included in successive iterations, for instance: iteration for task $t1$ ($Cr(t1)$),
   - We define matrix $Cr$ (communication due to cooperation within tasks) using the following formula:

$$Cr = ATr \cdot ATr' \tag{2.4}$$

where: $ATr$ is a matrix that consists of a column that corresponds to the task analysed.

c. Matrix $Qm$ is compared with every successive $Np$ matrix obtained during successive iterations:
   - If an element of a matrix (an arch that was removed from the optimal matrix in a given iteration) $qm_{ij} = 0$ in matrix $Qm$ and element $np_{ij} = 0$ in matrix $Np$, then move to the next iteration stage.
   - If element $qm_{ij} = 0$ in matrix $Qm$, and element $np_{ij} = 1$ in matrix $Np$, then compare the remaining elements of matrix $Np$ with elements of matrix $Qm$:
     - If there is at least one pair of elements for matrix $Qm$ and matrix $Np$ i.e. element $qm_{kl} = 1$ and element $np_{kl} = 1$ then move to the next iteration stage,
     - Otherwise, indicate this element in final matrix $Q_C$ and recall and save the task with its corresponding knowledge that was used in the iteration indicated for the creation of matrix $Cr$ giving it a delay value equal to one.

2.3. Communication due to task sequences:

a. A total of $s$ successive iterations are performed, whose number is equal to that of ones in matrix $TT$:
   - We point to identifiers of tasks that will be included in successive iterations, for instance (for instance: iteration for task $t_1$ ($Hs(t_1)$),
   - We define matrix $TTs$ that consists solely of the successive $r$-th one of matrix $TT$
   - We define matrix $Hs$ (communication due to task sequences) from the following formula:

$$Hs = AT \cdot TTs \cdot AT' \tag{2.5}$$

$U$ – set of row numbers from matrix $Hs$ that include non-zero values (set of agents who communicate with others as per matrix $Hs$),
$V$ – set of column numbers from matrix $Hs$ that include non-zero values (set of agents who communicate with agents included in set $U$).

b. Matrix $Qm$ is compared with every successive matrix $Hs$ obtained in successive iterations:
   - If an element of a matrix (an arch that was removed from the optimal matrix in a given iteration) $qm_{ij} = 0$ in matrix $Qm$ and element $hs_{ij} = 0$ in matrix $Hs$, then move to the next iteration stage.

- If element $qm_{ij} = 0$ in matrix $Qm$, and element $hs_{ij} = 1$ in matrix $Hs$, then compare other elements in matrix $Hs$ with elements in matrix $Qm$:
  - If there is at least one pair of elements for matrix $Qm$ and matrix $Hs$ i.e. element $qm_{kl} = 1$ and element $hs_{kl} = 1$ then move to the next iteration stage.
  - Otherwise, indicate this element in final matrix $Q_H$ and recall and save the task with its corresponding knowledge that was used in the iteration indicated for the creation of matrix $Hs$ giving it a delay value of one.

3. Matrices $Q_N$, $Q_C$, $Q_H$ are compared (after every set of iterations for a given removed arch–communication link):
   - If $qn_{ij} = 1$ or $qc_{ij} = 1$ or $qh_{ij} = 1$ then assume maximum delay time as per the previously assumed value
4. Using the critical path method (CPM) performance duration in a given period is calculated while accounting for delays in tasks indicated in a given iteration of matrix $Q$.
5. The cost of a lack of communication is calculated:
   - If the task is extended then the value of time extension should be multiplied by the cost of performance of a given task per day.

# 3. Case study

The case study concerns the construction of a multi-family housing complex (four six-storey buildings with underground car parks with a total usable floor area of 12,000 m$^2$) in Katowice, Poland. The project was constructed in the years 2016–2019, and its budget was around PLN 40 million. Up to September 2018, the project was being carried out using a general contractor system. Due to deteriorating conditions on the construction market, the General Contractor filed for bankruptcy, which resulted in the Developer hiring a managerial cadre and signing contracts directly with contractor companies that specialised in the various types of construction work. A new formal organisation structure was established for the project, and a new informal (self-organising) relationship structure between construction project participants emerged. In a previous study [27], the authors collected (via a survey) information from all project participants concerning communication and information flow between them throughout the first four weeks after the project's resumption. This communication was presented using a relation network of a self-organising communication structure. The authors also detected irregularities that appeared in the self-organising network [27, 28].

The stage of the proposed approach to planning and monitoring necessary communication within a construction project while accounting for the impact of a lack of communication on project completion time and cost includes four main stages:

1. The use of an optimal network of inter-participant communication generated using the previously proposed model [30], with the optimality denoting minimization of cost of necessary communication for a given project period (Fig. 1).

Table 2. Meta-network node description – participants (agents)

| Symbol | Description |
|---|---|
| A1 | Developer supervision coordinator |
| A2 | Electrical supervision coordinator |
| A3 | Sanitary supervision coordinator |
| A4 | Project Manager |
| A5 | Site manager |
| A6 | Works manager |
| A7 | Site engineer |
| A8 | Architect |
| A9 | Coordinator in charge of client amendments |
| A10 | Design office |
| A11 | Electrical services design office |
| A12 | Sanitary services design office |
| A13 | Company responsible for applying plaster |
| A14 | Company responsible for applying plaster finishes and drywalls |
| A15 | Electrical company |
| A16 | Subcontractor of the electrical company |
| A17 | Flooring company |
| A18 | Garage door supply and assembly company |
| A19 | Window supplier |
| A20 | Company building the roof and terraces |
| A21 | Door supplier |
| A22 | Central heating and plumbing services company |
| A23 | HVAC company |
| A24 | Facade and finish and balcony tiles company |
| A25 | Railing supply and assembly company |
| A26 | Masonry company erecting partition walls |
| A27 | External building services company |
| A28 | Landscaping company |
| A29 | Painting company |
| A30 | Passenger lift supply and assembly company |
| A31 | Ceramic tile company |
| A32 | Garage ceiling thermal insulation company |

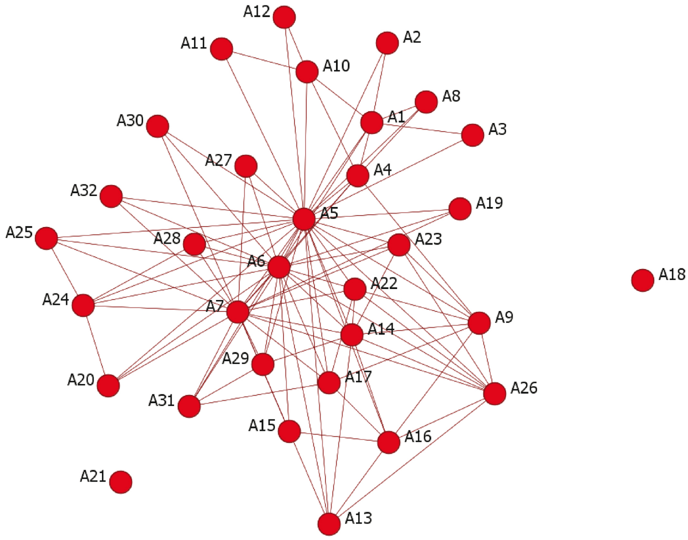


Fig. 1. Network AA – optimal (December), accounting for actual communication network for November. Network density 0.197. Highest degree centrality 0.875 (A5 Site manager)

2. Verification of the most essential communication links between participants in terms of their impact on project completion time, using the presented time-cost analysis algorithm (Fig. 2, Fig. 3).

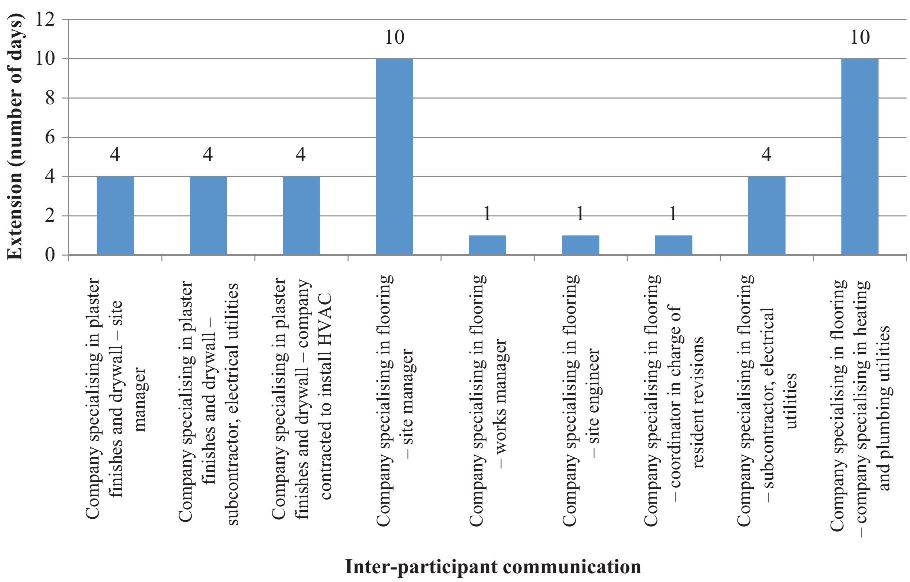


Fig. 2. Possible project extension in days due to lack of communication links between participants. The tasks they performed were on the critical path during the period under analysis (December)

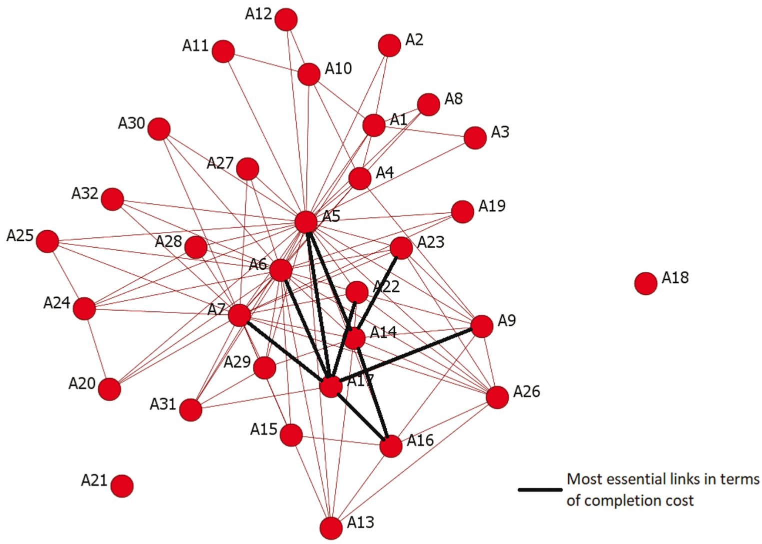


Fig. 3. Communication network AA – optimal (December), accounting for communication links whose lack would extend work completion time during the project period under analysis

3. Verification of the most essential communication links between participants in terms of their impact on project completion cost, utilizing the presented time-cost analysis algorithm (Fig. 4, Fig. 5).

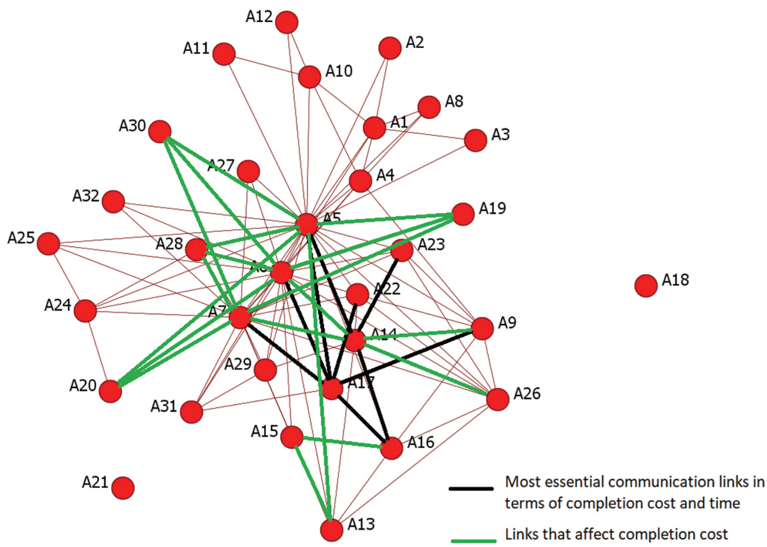


Fig. 4. Communication network AA – optimal (December), accounting for communication links whose lack would increase work completion cost during the project period under analysis

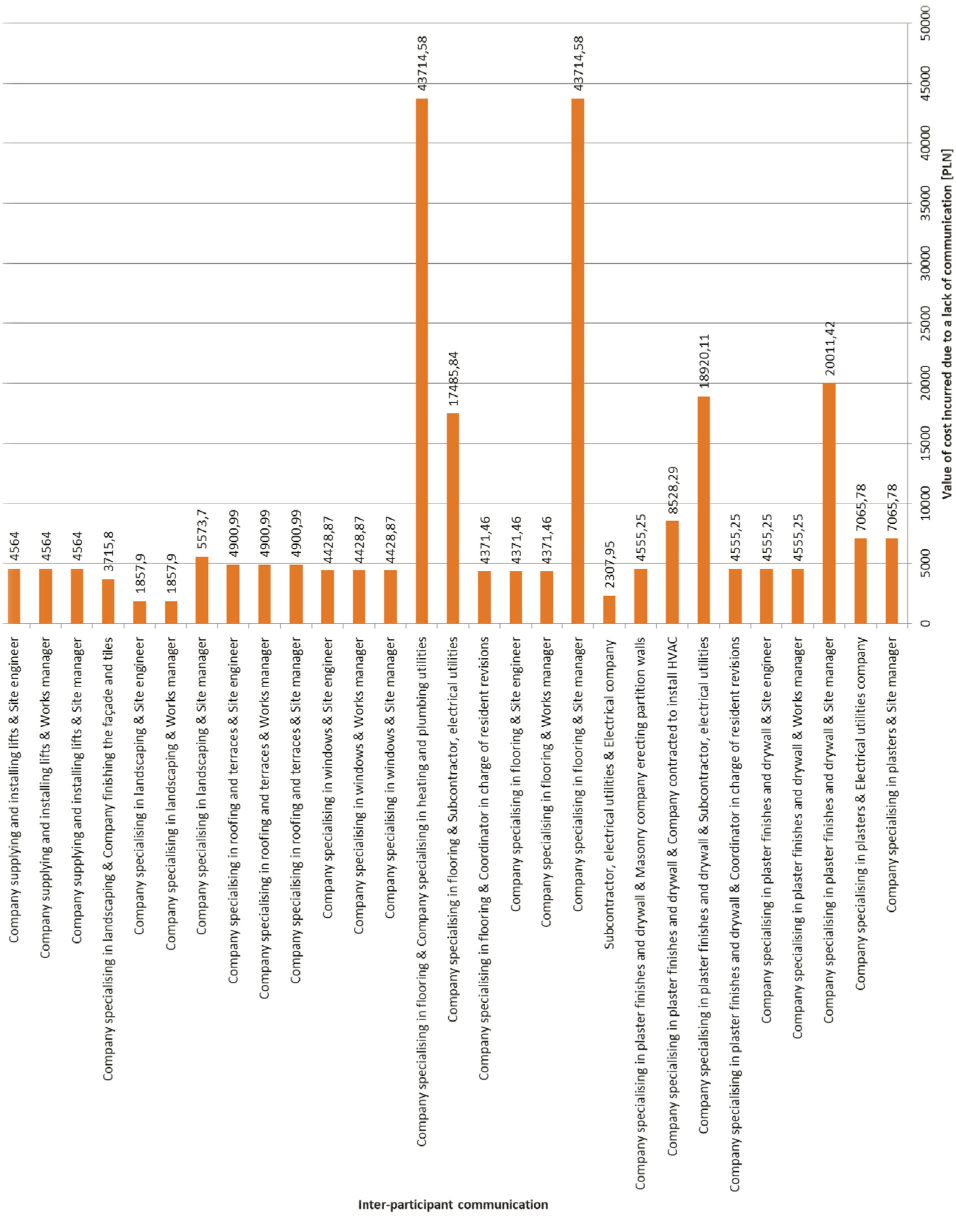


Fig. 5. Value of the cost of the lack of communication calculated as additional labour and equipment cost incurred by delays in work

The cost of the impact of a lack of information is calculated assuming that other resources such as materials, workforce and equipment, are available.

4. Introducing a plan of optimal necessary communication for the closest project execution period, with a particular emphasis on maintaining key links that affect time and cost increases. Afterwards, it is necessary to monitor communication and introduce corrective measures in cases where the planned necessary communication network is not adhered to.

The most popular method of implementing changes, indicated both in the literature [40] and by practitioners, is to present and discuss proposed changes during formal meetings between all project participants, i.e. project board meetings. When implementing the results, one should focus on the necessary communication paths and maintaining more key linkages (whose lack will cause an increase in cost and completion time), and thus unnecessary communication channels will be reduced to a minimum. One alternative to transferring information concerning optimal communication paths during project board meetings is using a multimedia application where such paths would be presented. The application should be personalised and include information on whom a given participant should contact on a given subject so as to obtain requisite information. It could include contact information within a participant's own micro-network of communication and should be updated as a project progresses.

# 4. Conclusions

As a result of their analysis, the authors demonstrated that the presence of problems with communication and information flow in a network of construction project participants during said project's execution phase affects the completion time and cost of the project. It is therefore crucial for the project manager to indicate optimal communication paths between participants within a given period, along with a comprehensive inclusion of the knowledge possessed and tasks worked on by said participants, together with a quantitative approach to assessing communication between construction project participants in the aspect of its impact on the time and cost of project completion and monitoring the communication network throughout the entire project cycle. Meta-network theory, which the authors used to model and analyse the problem, allowed them to properly address the complexity of this issue. The proposed method enables dynamic identification of key information flow paths between project participants, which significantly determine its performance. The effects of the analysis confirmed the application potential of the method.

The optimisation model developed, together with the module for analysing the impact of communication between participants on the time and cost of carrying out a construction project, can support decision-makers in more effectively managing communication between project participants, and thus provide more effective management of all tasks.

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## Analiza wpływu komunikacji pomiędzy uczestnikami przedsięwzięcia budowlanego na czas i koszt jego realizacji

**Słowa kluczowe:** Meta-Network Analysis (MNA), zarzadzanie w budownictwie, optymalizacja, przepływ informacji

### Streszczenie:

Wraz z rozwojem przemysłu budowlanego procesy budowlane stają się coraz bardziej dynamiczną, złożoną działalnością i zwiększa się świadomość potrzeby lepszego zarządzania przedsięwzięciami w przemyśle budowlanym [1]. Wynika to częściowo ze stawiania przez klientów coraz wyższych wymagań pod względem technologii, wydajności, oszczędności i szybkości projektowania oraz realizacji. Zmiany te sprawiają, że zarządzanie procesami projektowania budowlanego i wykonawstwa czyli koordynacja zaangażowania wielu zespołów stanowi poważne wyzwanie. Systemy komunikacji umożliwiają setkom ludzi realizowanie wielu zadań oraz koordynowanie ich wysiłków i umiejętności w kierunku osiągnięcia wspólnego celu [5]. Tematyka komunikacji i przepływu informacji w budownictwie jest poruszana w wielu badaniach [9–12]. Zjawisko komunikacji zazwyczaj polega na przekazywaniu informacji, jest to termin obejmujący takie znaczenia jak wiedza, przetworzone dane, umiejętności i technologia [13]. W budownictwie informacja jest wyjątkowo zróżnicowana, biorąc pod uwagę ogromną liczbę stron zaangażowanych w prace budowlane. Uczestnicy przedsięwzięcia mają potrzeby w zakresie wymaganych informacji i komunikacji. Określenie potrzeb informacyjnych zainteresowanych stron i określenie odpowiedniego sposobu zaspokojenia tych potrzeb są ważnymi czynnikami wpływającymi na sukces przedsięwzięcia. Należy zatem zidentyfikować uczestników przedsięwzięcia, określić ich potrzeby i oczekiwania, a następnie nimi zarządzać.

W badaniach nad zarządzaniem w budownictwie intensywnie rozwijana jest od dwóch dekad analiza organizacji przedsięwzięć budowlanych z perspektywy sieci. Aby analizować komunikację i przepływ informacji, które są uznawana za podstawę wspólnej pracy, a następnie ogólnej poprawy wydajności, jako skuteczne narzędzie wykorzystywano analizę sieci społecznych SNA (Social Network Analysis). Mimo to zastosowanie SNA do analizy komunikacji pomiędzy uczestnikami przedsięwzięcia nie umożliwia identyfikacji bezpośrednich czynników, które ją determinują, takich jak wpływ formalnej struktury organizacyjnej przedsięwzięcia, harmonogram realizacji robót oraz identyfikacja zasobów potrzebnej wiedzy do realizacji zadań. Autorzy niniejszego artykułu w publikacji [30] używając potencjał metasieci, wykorzystując dane dotyczące: formalnej struktury organizacyjnej przedsięwzięcia, harmonogramu realizacji zadań wraz z przypisanym do ich realizacji uczestnikami, informacją dotyczącą posiadanej wiedzy przez uczestników, która jest niezbędna przy realizacji poszczególnych zadań zaproponowali optymalizacyjne podejście do planowania i monitorowania wymaganej komunikacji pomiędzy uczestnikami realizowanego przedsięwzięcia budowlanego. Niniejszy artykuł jest kontynuacją wcześniejszych badań nad zarządzaniem komunikacją

i przepływem informacji pomiędzy uczestnikami przedsięwzięcia budowlanego. Zauważono bowiem, że zdecydowana większość badań [31–33] dotyczących wpływu komunikacji na czas i koszt realizacji przedsięwzięć budowlanych przyjmuje jakościowy charakter, brakuje analiz w ujęciu ilościowym omawianego tematu. Aby sprostać tym ograniczeniom autorzy niniejszego artykułu zaproponowali ilościowe podejście do oceny komunikacji pomiędzy uczestnikami przedsięwzięcia budowlanego w aspekcie jej wpływu na czas i koszt jego realizacji.

Celem artykułu jest przedstawienie opracowanego autorskiego algorytmu postępowania pozwalającego wyznaczyć wpływ braku komunikacji na czas i koszt przedsięwzięcia budowlanego. W celu uzyskania informacji jakie zadania w harmonogramie robót nie mogą zostać zrealizowane ze względu na brak komunikacji i przepływu informacji pomiędzy uczestnikami przedsięwzięcia budowlanego, i jakie będą tego skutki w kontekście czasu i kosztu przedsięwzięcia dokonano analizy wpływu usunięcia kolejnych łączy pomiędzy poszczególnymi uczestnikami w wyznaczonej optymalnej sieci komunikacji. Model został przedstawiony na przykładzie rzeczywistej realizacji osiedla mieszkaniowego.

W wyniku przeprowadzonej analizy, pokazano że występowanie problemów z komunikacją i przepływem informacji w sieci uczestników fazy realizacji przedsięwzięcia budowlanego wpływa na czas i koszty ich realizacji. Istotne jest więc wskazywanie przez zarządzającego przedsięwzięciem ścieżek optymalnej komunikacji pomiędzy uczestnikami w danym okresie z kompleksowym uwzględ-nieniem posiadanej przez uczestników wiedzy i realizowanych zadań wraz z ilościowym podejściem do oceny komunikacji pomiędzy uczestnikami przedsięwzięcia budowlanego w aspekcie jej wpływu na czas i koszt jego realizacji oraz monitorowanie sieci komunikacji przez cały cykl realizacji tego przedsięwzięcia. Wykorzystana przez autorów do modelowania i analizy problemu teoria metasieci pozwoliła na uchwycenie złożoności tego zagadnienia. Zaproponowana metoda umożliwia dynamiczną identyfikację kluczowych ścieżek przepływu informacji pomiędzy uczestnikami przedsięwzięcia, które w istotny sposób determinują jego wydajność. Efekty analizy potwierdziły potencjał aplikacyjny przedstawionej metody.

Opracowany model optymalizacyjny wraz z modułem analizy wpływu komunikacji pomiędzy uczestnikami na czas i koszt realizacji przedsięwzięcia budowlanego, może wspomagać decydenta w bardziej efektywnym zarządzaniu komunikacją pomiędzy uczestnikami przedsięwzięcia budowlanego, a co za tym idzie bardziej efektywnym zarządzaniem wszystkimi realizowanymi zadaniami.

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