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Research paper

Planning and monitoring communication between construction project participants

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Abstract: In the literature, researchers present construction projects as temporary self-organising coalition networks, composed of specialist entities that work towards set goals. The number of parties involved in the various processes during construction causes communications relations to be exceedingly complex and to change. The environment of a construction project is dynamic and complex, and self-organising communication networks are sensitive to institutional and social change. It becomes necessary to identify situations rooted in both insufficient communication during the carrying out of a project and its excess, which generates unnecessary cost. Effective control of information flow within self-organising communication networks through its planning and monitoring by project management can contribute to achieving project goals. This paper presents a proposal of an optimisation approach (in terms of minimising communication costs) to information flow planning that accounts for various constraints, on the example of a real-world case of building a housing complex in Poland.

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

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1. Introduction

Communication, understood as the flow of information between entities participating in projects, has its own specific challenges. The construction sector, in light of the current need for better performance through faster design and construction that take place simultaneously, is, to a degree, dependent on effective communication between individuals, teams and organisations. Construction projects can be characterised as temporary organisations that are interdisciplinary in character and that have are created to achieve specific goals in a set amount of time. These characteristics complicate communication, hindering direct information flow between participants [9]. The number of parties involved in the various processes during construction causes communications relations to be exceedingly complex and to change, which further highlights how dynamic they are.

Numerous authors [10, 19, 20, 31] have discussed the subject of communication in the construction sector, focusing on communications performance and investigating communication practices in construction companies. The authors of [9] highlighted that the complexity and dynamism of project structures within the construction sector can result in undermining the possibility of applying many central performance precepts in communication practices that have been successfully applied in other sectors. In reality, many management practices that evolved in response to structural conditions typical of construction had little regard for creating an open communication environment that can ensure well-connected teamwork, process integration and improved performance.

Communication is typically based on exchanging information. It is also a term with meanings denoting knowledge, processed data, skills and technologies [7]. In the construction sector, information is exceptionally diverse, particularly in light of the high number of parties involved in construction work.

The general significance of communication skills to the success of construction projects has been confirmed by Müller and Turner [18]. Yang, Huang and Wu [32] demonstrated the significant impact of teamwork on the success of a project, stressing that group communication is a critical function of teamwork. Furthermore, Jarvenpaa and Leidner [14] observed that trust between co-workers improved communication in a team that worked on a construction project. Ankrah et al. [3] performed an interview with nine experienced professionals who worked in the British construction industry. All of them stressed the significance of communication in construction projects. Radziszewska-Zielina and Kania demonstrated that the lack of effective communication between project participants can cause problems during the realisation of a construction project in the centre of an urban agglomeration [23]. Higgin, G. and Jessop [13] identified the primary problem areas in communication, which applied both to the design and construction phase of projects. Bankvall, Bygballe, Dubois and Jahre [4] argued that construction projects are highly complicated due to the interdependencies between various actions that must be effectively coordinated. As different project participants who work together as a team perform these actions, partnership and effective communication become key to a project's success [22, 24]. Kisielnicki [15] stated that network communication provides the most effective framework for project management.

For two decades, studies focusing on management in construction have seen intensive development of construction projects analysis from the perspective of networks. Many scholars have used Social Network Analysis (SNA) to analyse communication and information flow, which is considered a basis for joint work which is to be followed by a general improvement in performance. For instance, Pryke [21] used SNA to describe the impact of commission types on communication effectiveness in construction projects. Alsamadani, Hallowell & Javernick [1, 2] analysed communication frequency, communication methods and the impact of the structure of connections on its effectiveness for specialist work crews in the context of workplace health and safety. Brookes, Morton and Dainty [5] investigated project structures in the context of knowledge management and information flow. In [11], Di Marco, Taylor and Alin studied relations in the context of knowledge exchange and information flow in multicultural projects, discussing globalisation in networks. El Sheikh and Pryke [12] discussed the potential of SNA application in identifying gaps in communication networks.

However, the use of SNA to analyse communication between project participants does not allow us to identify the immediate factors that define it. The key to understanding the specificity of communication and, as a consequence, managing its course, is to understand the formal organisational structure of the project, analysing its schedule, its realisation, and identifying the necessary knowledge resources, the exchange of which determines the character of this communication.

The first paper in which the authors analysed the direct link between the character of communication between project participants and the project schedule was [8]. The authors stressed the significance of integrating social network analysis with task network analysis in the identification of the necessary communication and presented it on a practical example. The authors also noted the optimisation of information flow between project participants, criticising situations in which it is either insufficient or excessive, as this generates unnecessary communication costs. However, the work only focused on analysing the impact of the character and sequence of completing tasks on the communication in question, with little regard for the type of information required to analyse these tasks and sharing it among participants. Li, Y. K., Qian, L. L., He, Q. H., & Duan, Y. F. [17] included the aspect of necessary information and its possession by project participants. Using the potential of meta-networks for this end, the authors, using the construction of a Chinese car dealership chain, optimised the performance of these projects on the basis of assigning participants to each task depending on the knowledge they possessed or by supplementing its lack among participants by further training. However, the authors did not analyse the significance of and need for communication between participants with the aim of mutually sharing the missing knowledge required to carry out each task. The authors of this paper have attempted to address these shortcomings. We have proposed an optimisation approach to the planning and monitoring of the necessary communication between construction project participants. The optimisation was performed using data for a predefined formal organisational project structure, a task completion schedule with properly assigned participants for each task, as well as information about the knowledge possessed by the participants, which is required to perform each task.

2. Proposal of an approach to the planning and monitoring of necessary communication

2.1. Structural model of the problem

The authors used the concept of meta-networks to build the dependency structure between project participants, knowledge and tasks [16].

We are given a set of networks, each based on a directed graph composed of two sets of elements, U and V, and a relations set: $E \subset U \times V$. Each pair of elements $(i, j) \in E$ for $i \in U$ and$j \in V$, denotes a relation between i and j. Sets of networks that demonstrate such relationships are called meta-networks [17, 27, 28].

The network set integrated 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 featuring matrices that represent six types of matrices within three node classes

V \ U	A (Agent)	K (Knowledge)	T (Task)
A (Agent)	(AA) Who communicates with whom	(AK) What knowledge does the agent have	(AT) What tasks does the agent perform

K (Knowledge)	*	(KK) What is the dependency between specific pieces of knowledge	(KT) What tasks can be performed with this knowledge
T (Task)	*	*	(TT) What is the dependence between tasks

Single-mode networks are represented by square adjacency matrices which define relationships within one node class: matrix "AA" encompasses agent-to-agent relations (between individuals or organisations), matrix "TT" encompasses dependencies between tasks, and so on and so forth. Matrices outside of the meta-matrix diagonal represent two-mode networks—dependencies between two node classes, e.g. matrix "AK" encompasses relations between agents and knowledge.

2.2. Meta-network structural analysis

The literature features many structural measures that provide different types of information about the dependencies that are modelled. These measures were formulated for single-mode networks [30] and multi-modal networks [26].

For the purposes of this paper, the following structural measures were used in the context of analysing necessary communication within construction projects [6].

Matrix H for the necessary communication between agents assigned to perform tasks in a sequence of direct precedence.

$$H = AT \cdot TT \cdot AT', \tag{2.1}$$

Matrix C for the necessary communication between agents assigned to perform the same tasks:

$$C = AT \cdot AT', \tag{2.2}$$

Matrix *N* for the necessary communication between agents who should transfer knowledge necessary for task completion between themselves:

$$N = AT \cdot Z \cdot AK' \quad with \quad Z(t,k) = \begin{cases} 1, & where\ [AT' \cdot AK - KT'] < 0 \\ 0, & otherwise \end{cases}, \tag{2.3}$$

Matrix Q will be a summary matrix of necessary communication between *m* agents:

(2.4) $$Q\,(t;\,r) = \begin{cases} 1, where\ [(H + C + N) + (H + C + N)'] > 0 \\ 0,\ otherwiseie \end{cases}$$

The matrix *Q* obtained from the formulae presented above for a given set period (e.g. within a monthly cycle) of project completion typically requires tweaking due to the excess of communication it describes. Furthermore, this matrix should be supplemented to include formal communication resulting from a predetermined project organisation structure. The analysis is to eliminate excessive communication and optimise the structure of communication links between agents, minimising communication costs. The optimisation will show a preference for pre-existing communication links from the previous project cycle.

2.3. Necessary communication optimisation model

Below is a presentation of the procedure intended to determine the mathematical optimisation model that utilises binary integral linear programming.

Step. 1

Calculate matrix F (communication arising from the project's formal organisation structure).

Step. 2

Calculate matrix *Z* (of the knowledge necessary to complete each task) using the formula below:

(2.5) $$\mathrm{Z}(t,k) = \begin{cases} 1, & where\ [\,AT' \cdot AK - KT'] < 0 \\ 0, & otherwise \end{cases}$$

Step 3

We perform *p* successive iterations, whose number is equal to the number of ones present in matrix Z.

- We assume matrix Z_p , composed solely of the subsequent *p*th one of matrix Z.
- We calculate matrix N_p (communication necessary due to the knowledge required to complete a task) using the formula $N_p = AT * Z_p * AK'$
- K-is the set including the number of rows of matrix N_p which contain non-zero values (the set of agents who communicate with other agents as per matrix N_p)

- L-is the set including the number of columns of matrix N_p which contain non-zero values (the set of agents who engage in communication with agents defined by set K)

For iteration p, we define a constraint that states that at least one agent from set K should communicate with at least one agent from set L:

$$\sum_{k\epsilon K, j\epsilon L} q_{kj} \geq 1 \quad (2.6)$$

Step 4

We perform r successive iterations, equal to the number of columns (tasks) in matrix AT

- if the sum in column r of matrix $AT = 1$ (one agent assigned to the task), we move on to the next step of the iteration
- if the sum in column r of matrix $AT > 1$, then we assume matrix AT_r comprised of this column only
- we calculate matrix C_r (communication necessary for cooperation within tasks) from the formula $C_r = AT_r * AT_r'$

For iteration r, we introduce a constraint that states that agents assigned to the same task should communicate with each other

$$q_{ij} >= cr_{ij}\ , for\ i, j\ \in m \quad (2.7)$$

Step 5

We perform s successive iterations in the number equal to the number of ones in matrix TT.

- we assume matrix TT_s composed entirely of the subsequent sth one of matrix TT
- we calculate matrix H_s (communication necessary due to task sequence) using the formula:

$$H_s = AT * TT_s * AT' \quad (2.8)$$

- U-is the set of the number of rows of matrix H_s which contain non-zero values (the set of agents who communicate with other agents as per matrix H_s)
- V-is the set of the number of columns of matrix H_s which contain non-zero values (the set of agents who engage in communication with agents defined by set U)

For iteration s, we introduce a constraint that states that at least one agent from set U should communicate with at least one agent from set V (at least one agent performing a task should communicate with at least one agent performing the subsequent task):

$$\sum_{u \epsilon U, v \epsilon V} q_{uv} \geq 1 \tag{2.9}$$

Step 6

We formulate additional constraining conditions:

$$q_{ij} = bin \tag{2.10}$$

$$q_{ij} >= f_{ij}, \text{ for } i, j \in m, \tag{2.11}$$

so that communication is maintained due to the project's formal organisational structure

$$q_{ij} = q_{ji}, \text{ for } i, j \in m, \tag{2.12}$$

so that communication between agents can be bi-directional

Step 7

We calculate the optimal matrix Q (the necessary communication matrix) by assuming the following goal function:

$$\sum_{i,j \epsilon m} q_{ij} - 0.01 \sum_{i,j \epsilon m} q_{ij} \cdot b_{ij} \rightarrow min \tag{2.13}$$

- the first element is responsible for minimising the number of connections denoting inter-agent communication
- the second element is responsible for maintaining previous inter-agent communication (its low weight makes it the deciding factor when multiple Q matrices with the same number of connections that meet constraints are present)

3. Case study

The case study focuses on 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. The project was being carried out since the beginning of 2016 and was completed in December 2019. The project budget was around 40 million PLN. Up to 2018, the project was being carried out using the general contractor system. Due to the worsening situation on the construction market, the General Contractor filed for bankruptcy, which caused the Developer to employ management staff and sign contracts directly with construction companies who specialised in specific types of construction work. A new formal project organisational structure was formed, in addition to a new informal (self-organising) relationship structure between project participants. In a previous study [29] the authors collected (via a survey) information from all project participants concerning inter-participant communication during the first four weeks after the project's resumption. The communication structure was presented using a self-organising network. The authors also identified irregularities which appeared within this communication network [25, 29].

The proposed approach to the planning and monitoring of necessary communication within construction projects includes four essential stages:

1. Preparing data concerning: planned task sequence, project participants, the knowledge they possess and the knowledge required to complete tasks for the upcoming, preset period of carrying out the project (e.g. in a monthly cycle). Furthermore, data concerning the preset information exchange between project participants arising from the project's formal organisational structure are required.
2. Defining the structure of dependencies between participants, knowledge and project tasks with the use of meta-networks. Meta-networks for November and December have been presented in figures 1 and 2, respectively (meta-network node descriptions have been presented in tables 2, 3 and 4).

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

Table 3. Meta-network node description—knowledge

Symbol	Description
K1	Technical design
K2	Detailed design - architecture
K3	Detailed design - structural system
K4	Detailed design - plumbing services
K5	Detailed design - electrical services
K6	Client amendment protocols
K7	Surveying documentation (axis demarcation and as-built documentation)
K8	Facade works handover protocols
K9	Plumbing services handover protocols (tightness tests)
K10	Electrical services handover protocols
K11	External building services handover protocols
K12	HVAC handover protocols
K13	Technical approvals and compliance statements
K14	Material approval protocols
K15	Concrete strength test protocols

Table 4. Meta-network node description—tasks

Symbol	Description
T1	Reinforced concrete railing handrail delivery and assembly Bld B
T2	Northern facade, light-wet method Bld B
T3	Southern facade, light-wet method Bld B
T4	Western facade, light-wet mehod Bld B
T5	Balcony insulation Bld B
T6	Western facade - laying tiles on balconies Bld B
T7	Southern facade - laying tiles on balconies Bld B
T8	Western facade - balcony railings delivery and assembly Bld B
T9	Southern facade - balcony railings delivery and assembly Bld B
T10	Reinforced concrete railing flashing Bld B
T11	Primary electrical services Bld B
T12	Electrical services in apartments and premises Bld B

T13	Plasters Bld B
T14	Applying putty to partition walls Bld B
T15	Floor laying Bld B
T16	Apartment and corridor insulation mats (drywalls) Bld B
T17	Plumbing and storm drain services Bld B
T18	Domestic hot water services Bld B
T19	Central heating services Bld B
T20	Mechanical ventilation Bld B
T21	Assembly of technical doors and doors to tenant storage rooms Bld B
T22	Garage door assembly Bld B
T23	Western facade - roads and pavements Bld B
T24	Building partition walls Bld C
T25	Plasters Bld C
T26	Applying putty to partition walls Bld C
T27	Window montage Bld C
T28	Primary electrical services C
T29	Electrical services in apartments and premises Bld C
T30	Plumbing and storm drain services Bld C
T31	Domestic hot water services Bld C
T32	Central heating services Bld C
T33	Mechanical ventilation Bld C
T34	External works—drainage and storm drain grid Bld C
T35	External works—water supply connection Bld C
T36	Storm drain connection Bld C
T37	Sewerage connection Bld C
T38	Water supply connection Bld C
T39	Building partition walls Bld D
T40	Building tenant storage rooms Bld D
T41	Eastern facade, light-wet method Bld B
T42	Eastern facade - laying tiles on balconies Bld B
T43	Eastern facade - delivery and assembly of balcony railings Bld B
T44	Applying first coat of paint to corridors and stairwells Bld B
T45	Laying tiles in corridors and stairwells Bld B
T46	Passenger lift assembly
T47	Northern facade - roads, pavements, main entrance Bld B
T48	Garage ceiling thermal insulation application Bld C
T49	Service shafts Bld C
T50	Applying putty to service shafts Bld C
T51	Window montage Bld D
T52	Flat roof - thermal insulation and roofing
T53	Garage ceiling thermal insulation application Bld D

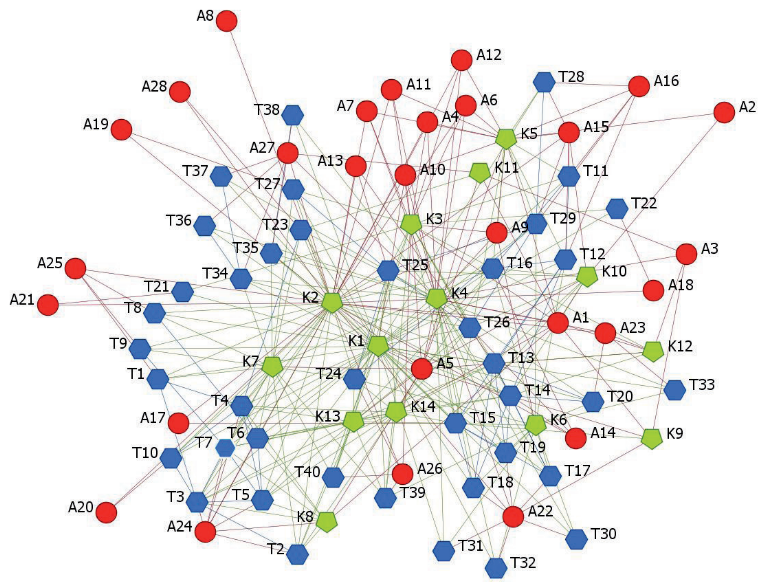

Fig. 1. Meta-network – November

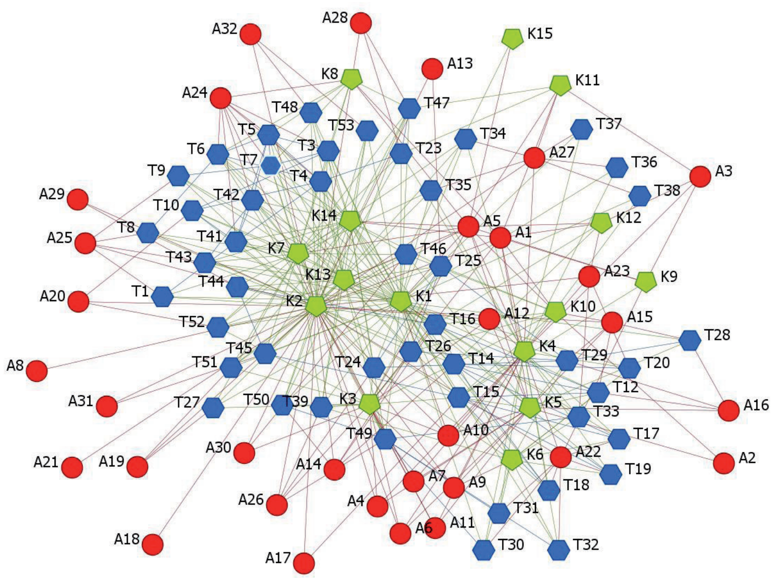

Fig. 2. Meta-network – December

3. Generating an optimal communication network as per the model presented in section 2.3 for the given project completion period. Figure 3 presents the actual communication network for November, while figures 4 and 5 present optimal communication networks for November and December, respectively. The communication networks in figures 3, 4 and 5 were characterised using basic structural measures [30] such as: density, which is the ratio between the number of existing communication links and all of the possible links within the network, and the degree centrality of the node, which determines the number of direct links between a given node and other network nodes. The greater the degree centrality, the more significant a given node is within the network in terms of communication. The proposed optimisation model was implemented using the Python programming language, using the CVXPY library for linear optimisation.

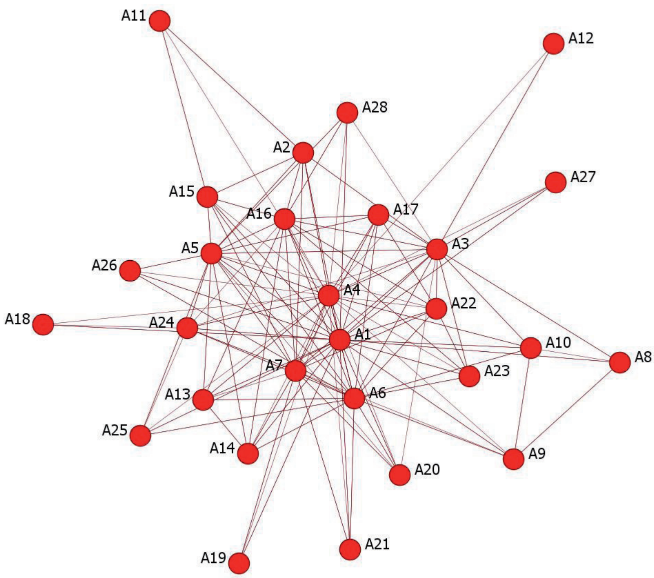

Fig. 3 Network AA – actual, data collected during project in November. Network density 0.287. Highest degree centrality 0,893 (A1 Developer supervision coordinator)

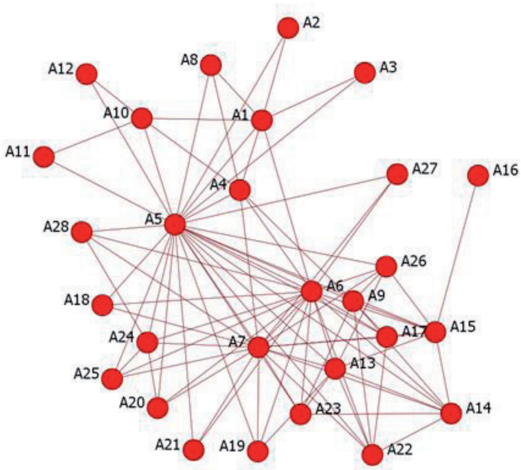

Fig. 4 Network AA – optimal (November). Network density 0.235. highest degree centrality 0,929 (A5 Site manager)

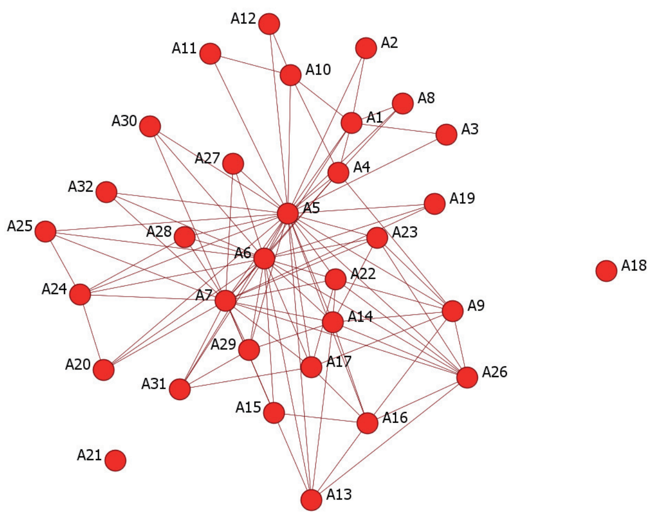

Fig. 5 Network AA – optimal (December), accounting for actual communication network for November. Network density 0.197. Highest degree centrality 0,875 (A5 Site manager)

4. Introducing an optimal communication plan for the upcoming project completion cycle and monitoring its implementation.

3. Conclusions

Based on the analysis presented above, it was demonstrated that communication within the network of participants of a construction project's realisation phase is dynamic, as it constantly changes (evolves) and adapts to the project's goals. Based on a structural analysis of the actual communication network for November and the optimal communication network for November and December, the authors highlighted key irregularities and differences in communication. When analysing the network in question based on the values of basic structural measures, it was observed that the density of the actual network for November was higher than that of its optimal version, which generates additional communication costs because of excess communication. The key difference between these two networks is that the actual communication network has the Developer supervision coordinator as its central agent, while the optimal networks for November and December showed that it was the Site manager who had the highest degree centrality, and who was evidently poorly connected in the actual communication network (Site manager degree centrality of 0.535 in the actual network for November and 0.929 in the optimal network for December).

It is therefore essential for the project manager to identify optimal communication paths between agents for a given period while comprehensively accounting for their knowledge and the tasks they perform and to monitor the communication network across the entire project completion cycle. The optimisation model developed for this purpose, thanks to the use of meta-network analysis, can aid the decision-maker in more effectively managing communication between the participants of construction projects and therefore in being more effective in managing all tasks. The outcome of the analysis confirmed the application potential of the presented approach. Further research should focus on determining communication cost in monetary units and on accounting for its difference depending on each participant. Studies should also be continued by differentiating communication based on significance, particularly focusing on critical communication links in relation to critical tasks. Such analyses require the introduction of weighted networks. Regardless of the above, the fact that optimising the network in terms of the minimum necessary communication links (minimal communication costs) makes the network less resistant to factors that disrupt communication due to the loss of certain links or nodes (e.g. as a result of the absence of communicating participants with the knowledge required to complete a task) should be investigated further. Therefore, the proposed optimisation model should be developed so as to allow to generate affordable communication networks that will also display sufficient resistance to factors that disrupt information flow between project participants.

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Planowanie i monitorowanie komunikacji pomiędzy uczestnikami przedsięwzięcia budowlanego

Kluczowe słowa: Meta-Network Analysis (MNA), zarzadzanie w budownictwie, optymalizacja, przepływ informacji

Streszczenie:

W literaturze przedmiotu badacze przedstawiają przedsięwzięcie budowalne jako tymczasową samoorganizującą się sieć koalicyjną składającą się ze specjalistycznych podmiotów realizujących założone cele. Środowisko przedsięwzięcia budowlanego jest dynamiczne i skomplikowane, a samoorganizująca się sieć komunikacji jest wrażliwa na zmiany instytucjonalne i społeczne. Koniecznością staje się identyfikacja sytuacji zarówno niedoboru komunikacji w ramach realizacji przedsięwzięcia jak i jej nadmiarowości, która generuje niepotrzebne koszty.

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).

Jednak wykorzystanie SNA do analizy komunikacji pomiędzy uczestnikami przedsięwzięcia nie pozwala na identyfikację bezpośrednich czynników, które ją determinują Kluczem do zrozumienia specyfiki komunikacji i w konsekwencji zarządzania jej przebiegiem jest przede wszystkim zrozumienie formalnej struktury organizacyjnej przedsięwzięcia, analiza harmonogramu jego realizacji oraz identyfikacja zasobów potrzebnej wiedzy, której wymiana pomiędzy uczestnikami determinuje charakter tej komunikacji.

Autorzy niniejszego artykułu wyszli naprzeciw ograniczeniom w badaniach [17] i na podstawie danych dotyczących formalnej struktury organizacyjnej przedsięwzięcia, harmonogramu realizacji zadań z przypisaniem uczestników do ich realizacji a także informacji na temat posiadanej wiedzy przez uczestników, która jest potrzebna do realizacji poszczególnych zadań zaproponowali optymalizacyjne podejście do planowania i monitorowania wymaganej komunikacji pomiędzy uczestnikami realizowanego przedsięwzięcia budowlanego. Na potrzeby budowy struktury zależności pomiędzy uczestnikami, wiedzą i zadaniami przedsięwzięcia wykorzystano koncepcję meta-sieci [16].

W literaturze przedmiotu zostało opracowanych wiele miar strukturalnych które dostarczają różnych informacji o modelowanych zależnościach. Miary takie opracowano zarówno dla sieci jednomodowych [30] jak i wielomodowych [26] i zostały one wykorzystane na potrzeby niniejszego artykułu w kontekście analizy wymaganej komunikacji w przedsięwzięciu budowlanym. Otrzymana z analizy strukturalnej macierz wymaganej komunikacji Q dla danego ustalonego okresu (np. w cyklu miesięcznym) realizacji przedsięwzięcia zwykle wymaga korekty ze względu na nadmiarowość określonej w niej komunikacji. Dodatkowo macierz tą należy uzupełnić o formalną komunikację wynikającą z odgórnie narzuconej struktury organizacyjnej danego przedsięwzięcia. Oczekiwanym rezultatem przedmiotowej analizy będzie więc likwidacja nadmiarowości komunikacji i optymalizacja struktury połączeń komunikacyjnych pomiędzy agentami minimalizująca koszty tej komunikacji. W ramach optymalizacji preferowane będą już istniejące połączenia komunikacyjne z poprzedniego okresu realizacji przedsięwzięcia.

Celem artykułu jest przedstawienie propozycji optymalizacyjnego (pod względem minimalizacji kosztów komunikacji) podejścia do planowania przepływu informacji z uwzględnieniem różnych ograniczeń. Model został przedstawiony na przykładzie rzeczywistej realizacji osiedla mieszkaniowego.

W wyniku analizy strukturalnej rzeczywistej sieci komunikacji w listopadzie (dane zebrane z przedsięwzięcia) oraz optymalnej sieci komunikacji w listopadzie i grudniu (dane otrzymane z modelu) zwrócono uwagę na istotne nieprawidłowości i różnice w komunikacji. Analizując przedmiotową sieć w oparciu o wartości podstawowych miar strukturalnych zauważono że gęstość sieci rzeczywistej w listopadzie jest wyższa od optymalnej sieci listopadowej, co generuje dodatkowy koszt komunikacji. Istotna różnicą w obu tych sieciach jest fakt że w rzeczywistej sieci komunikacji centralną postacią jest Koordynator Nadzoru Inwestorskiego natomiast w sieci optymalnej, zarówno listopadowej jaki i grudniowej najwyższy stopień centralności posiada Kierownik Budowy.

Istotne jest więc wskazywanie przez zarządzającego przedsięwzięciem ścieżek optymalnej komunikacji pomiędzy uczestnikami w danym okresie z kompleksowym uwzględnieniem posiadanej przez uczestników wiedzy i realizowanych zadań oraz monitorowanie sieci komunikacji przez cały cykl realizacji tego przedsięwzięcia. Opracowany w tym celu model optymalizacyjny, dzięki zastosowaniu analizy Meta-sieci, może wspomagać decydenta w bardziej efektywnym zarzadzaniu komunikacją pomiędzy uczestnikami realizacji przedsięwzięcia budowlanego, a co za tym idzie bardziej efektywnym zarządzaniem wszystkimi realizowanymi zadaniami. Efekty analizy potwierdziły potencjał aplikacyjny przedstawionej metody. Kierunki dalszych badań powinny skupić się na określeniu kosztu komunikacji w jednostkach pieniężnych oraz uwzględnieniu jego zróżnicowania ze względu na poszczególnych uczestników. Należy także kontynuować badania różnicując komunikację ze względu na jej istotność, szczególnie zwracając uwagę na krytyczne połączenia komunikacyjne w nawiązaniu do realizacji zadań krytycznych. Takie analizy wymagają wprowadzenia tzw. sieci ważonych. Niezależnie od powyższego należy również zwrócić uwagę na fakt że optymalizacja sieci pod względem minimalnej liczby wymaganych połączeń komunikacyjnych (minimalne koszty komunikacji) czyni sieć mniej odporną na czynniki powodujące zaburzenia w komunikacji ze względu na utratę niektórych jej połączeń lub węzłów (np. w wyniku absencji komunikujących się uczestników z daną wiedzą potrzebna do realizacji konkretnych zadań). W przyszłości należy więc rozwijać proponowany model optymalizacyjny, który pozwoli wygenerować tanią sieć komunikacji, która równocześnie wykazywała będzie dostateczną odporność na czynniki zaburzające przepływ informacji pomiędzy uczestnikami przedsięwzięcia.

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