ZAŁĄCZNIK 3

Autoreferat przedstawiający opis dorobku i osiągnięć naukowych w języku angielskim

Summary of professional accomplishments

1. Name and Surname

Piotr Jaśkowski

2. Degrees and titles (type, time of award, titles of theses)

I graduated from the Politechnika Lubelska, Faculty of Civil Engineering, with a masters degree (M.Sc. Eng.) in construction, specialty construction methods and management. My master thesis, *Shaping the buildings: ergonomics in architecture*, was supervised by Teresa Taczanowska, Ph.D. Eng. and Elżbieta Przesmycka, Ph.D. Arch. Eng. I defended the thesis on 18th July 1995 and graduated with distinction.

I received a doctoral degree (PhD. Eng.) in construction from the Politechnika Lubelska, Faculty of Civil Engineering, on 18th November 2003. My thesis, *Method of designing the structure of the construction project's operating system*, was written under supervision of Anna Sobotka, Ph.D. Hab. Eng., and reviewed by Oleg Kapliński, Prof. Ph.D. Hab. Eng., and Tadeusz Kasprowicz, Prof. Ph.D. Hab. Eng. The quality of the dissertation was recognized by the Board of the Faculty of Civil Engineering who awarded me a degree with distinction. The dissertation was submitted to the Best Dissertation Competition by the Minister of Infrastructure and won a prize on 22nd April 2005.

3. Previous and current employment at scientific institutions

On 1st October 1995 I was appointed research a teaching assistant at the Politechnika Lubelska, Faculty of Civil Engineering, Department of Construction Methods and Management (later the Division of Construction and Investment Process Engineering of the Institute of Construction).

On 1st February 2004 I was promoted to assistant professor (adiunkt), and on 28th November I was entrusted the duties of the Head of the Division of Construction and Investment Process Engineering of the Institute of Construction. After reorganization of the Faculty, since 1st October 2012, I am Acting Head of the Department of Construction Methods and Management at the Faculty of Civil Engineering and Architecture, Politechnika Lubelska.

Additionally, since 1st October 2009, I have been employed as senior lecturer at the Chair of Construction, the Institute of Applied Sciences and Aviation, the State School of Higher Education in Chełm; initially it was a part-time position, in years 2011 – 2013 full time and since October 2011 – part-time.

4. Achievements according to Article 16 Point 2 of the Law of 14 March 2003 r. on scientific degrees and scientific title and on degrees and title in art (Dz.U. nr 65, poz. 595 ze zm.)

4 a. Basis of the application

The basis for my applying for habilitation in applied sciences, discipline of construction, is a series of publications with a common subject:

"METHODOLOGY FOR ENHANCING RELIABILITY OF PREDICTIVE PROJECT SCHEDULES IN CONSTRUCTION".

The results of my research in this field took the form of 15 papers published in Polish and international scientific journals. They are listed in Section 4b followed, in Section 4c, by a concise description of my scientific achievement in the field of modeling risk, and developing non-deterministic planning approaches for construction projects aimed at improving schedule reliability and robustness in random environment.

4 b. List of publications – basis for application for habilitation

1. Czarnigowska A., **Jaśkowski P.**, Sobotka A.: Zastosowanie metody *critical chain scheduling* (CCS) w przedsięwzięciach budowlanych (Application of Critical Chain

Scheduling (CCS) to construction project planning). Przegląd Organizacji nr 11/2004, s. 22–26. MS&HE score 7 (2014).

2. Biruk S., **Jaśkowski P.**: Simulation modelling construction project with repetitive tasks using Petri nets theory. Journal of Business Economics and Management. Vilnius: Technika, Vol. 9, No. 3, 2008, pp. 219–226. Impact factor 3,866. MS&HE score 25 (2014).

3. **Jaśkowski P.**, Biruk S.: The work continuity constraints problem in construction projects' network models, Archives of Civil Engineering, LV, 1, 2009, pp. 29–41. MS&HE score 6 (2014).

4. **Jaśkowski P.**, Biruk S., Bucoń R.: Assessing contractor selection criteria weights with fuzzy AHP method application in group decision environment. Automation in Construction, Vol. 19, No. 2, 2010, pp. 120–126. Impact factor 1,311. MS&HE score 40 (2014).

5. **Jaśkowski P.**, Biruk S.: Analiza czynników ryzyka czasu realizacji przedsięwzięć budowlanych (Analysis of duration risk factors in construction projects). Czasopismo Techniczne z. 2/2010, seria Budownictwo, 2.1B/2010, s. 157–166. MS&HE score 6 (2014).

6. Biruk S., **Jaśkowski P.**: Harmonogramowanie przedsięwzięć wieloobiektowych z ciągłą realizacją procesów na działkach roboczych (Multi–object project scheduling with assumption of process continuity). Zeszyty Naukowe Wyższej Szkoły Oficerskiej Wojsk Lądowych im. gen. T. Kościuszki we Wrocławiu, Rocznik XLII, 3(157), Lipiec–Wrzesień 2010, s. 340–349. MS&HE score 4 (2014).

7. **Jaśkowski P.**, Biruk S., Painting N.: Using fuzzy AHP for assessing risk of construction projects. International Journal of Arts & Sciences, Vol. 4, No. 19, 2011, pp. 257–268. MS&HE score 8 (2012).

8. **Jaśkowski P.**, Biruk S.: The method for improving stability of construction project schedules through buffer allocation. Technological and Economic Development of Economy, Vol. 17, No. 3, 2011, pp. 429–444. Impact factor 5,605. MS&HE score 35 (2014), 45 (2012).

9. **Jaśkowski P.**, Biruk S.: The conceptual framework for construction project risk assessment. Reliability: Theory & Applications (Electronic Journal Reliability & Risk Analysis: Theory & Applications), Vol. 2, No. 3(22), 2011, pp. 27–35. MS&HE score 6 (2012).

10. **Jaśkowski P.**, Biruk S.: Ocena porównawcza mierników odporności harmonogramów budowlanych (Comparing measures of construction schedule robustness). Civil and Environmental Engineering / Budownictwo i Inżynieria Środowiska, Vol. 2, No. 4, 2011, pp. 501–505. MS&HE score 2 (2012).

11. **Jaśkowski P.**, Biruk S., Kowalski T.: Trade–off between robustness of a construction schedule and project completion time. International Journal of Arts & Sciences, Vol. 4, No. 20, 2011, pp. 205–215. MS&HE score 8 (2012).

12. **Jaśkowski P.**: Model negocjacji uczestników łańcucha dostaw w budownictwie z zastosowaniem teorii gier wieloosobowych (A supply chain negotiation model based on many–pleyer game theory). Gospodarka Materiałowa i Logistyka, nr 3/2012, s. 8–12. MS&HE score 8 (2012), 7 (2014).

13. **Jaśkowski P.**, Sobotka A.: Using soft precedence relations for reduction of the construction project duration. Technological and Economic Development of Economy, Vol. 18, No. 2, 2012, pp. 262–279. Impact factor 3,224. MS&HE score 35 (2014), 45 (2012).

14. **Jaśkowski P.**: Multi–skilled resources allocation models for project scheduling in construction. In: Skorupka D. (Ed.): Scientific problems in management : project management, risk management, human resource management, economic aspects of management. Wyższa Szkoła Wojsk Lądowych im. generała Tadeusza Kościuszki, Wrocław 2013, s. 51–58. MS&HE score 5 (2014).

15. **Jaśkowski P.**: Metodyka zwiększenia niezawodności predyktywnych harmonogramów realizacji przedsięwzięć budowlanych / Methodology for enhancing reliability of predictive project schedules in construction. Eksploatacja i Niezawodność – Maintenance and Reliability, Vol. 17, No. 3, 2015, pp. 471–480. Impact factor 0,505. MS&HE score 15 (2014).

4c. Aims of the aforementioned work and comments on the results and their possible application

A construction project is an economic venture. As any complex process aimed at efficiency, it needs to be planned and organized – with consideration to its particular conditions and environment, and with regard to the state-of-the-art in science and technology. Project scheduling is aimed at planning project activities in time – and has been a core concern of practitioners and researchers worldwide. Project scheduling was also the subject of my doctoral dissertation.

Scheduling techniques have been developed for decades to allow, as accurately as possible, for the real-life conditions such as limited resource availability and randomness. Construction activities and construction projects are especially prone to risk, much more than activities in other branches of economy. Therefore, a practical scheduling method dedicated for construction should, in order to assure reliability of planning, limit the unfavourable effects of risks and uncertainty on the course of action and project efficiency – in other words, it should enable the user to create schedules not sensitive to random occurrences. A good schedule should provide the user with reliable target dates. Thus, current trends in project management research focus on robust methods in project planning. Predictive (or proactive) scheduling belongs to these trends, and its products are to be stable and not "nervous" to the real-life interferences. A schedule's robustness against interference is understood as its ability to cope with relatively small delays in processes caused by risk factors and uncertainties.

Assuring robustness of a schedule one improves its reliability. The reliability is understood as probability of the schedule's conforming to the initial requirements on the completion time of particular processes and the project as a whole.

Reduction of the schedule sensitivity to interference is possible with application of the contingency technique (so by estimating process duration with an allowance for a given level of reliability), or by a more efficient redundancy technique (following the Goldratt's Theory of Constraints and Critical Chain) that, among others, uses time buffers carefully distributed throughout the schedule in anticipation of disturbance and to minimize deviation from the scheduled starting times.

The main aim of my investigations was to provide a methodology for designing predictive schedules of construction projects to improve their reliability. The results of these investigations were presented in a series of publications – being my major achievement in science. The proactive approach adopted in them was aimed to reduce discrepancies between as-planned and actual process start dates notwithstanding effects of random occurrences and unfavourable conditions. Allowing for risks and uncertainty – on the basis of a thorough analysis of project particularities provides for realistic plans and contracting resources in a reliable way. Scheduling resources in stochastic environment makes it easier to coordinate project portfolios for both the general contractor and the subcontractor, and to plan ancillary production and supplies. It also reduced propagation of disruptions to other projects in the portfolio. A tangible result of my research is an original method of analyzing and assessing risk. The method is based on a multi-attribute analysis of project conditions. The analysis provides a necessary input for preparation of predictive schedules.

The major part of my work was done within the framework of a research grant "Designing robust construction schedules with multi-attribute assessment of the impact of operating conditions" where I assumed the role of the project manager. The project was funded by the Polish Ministry of Science and Higher Education.

The proposed methodology of improving reliability of construction project schedules covers two interrelated stages: a construction duration risk assessment and the allocation of time buffers in the schedule. A detailed description of the predictive schedule design procedure was presented in [15]; this paper summarizes results of my investigations. The remaining papers of the series present the original decision support methodology to be applied at each stage of the aforementioned procedure, namely a methodology for evaluating process duration risk level, defining significance of operating conditions, estimating dispersion of process durations, and defining criticality of processes in the schedule. A set of measures of schedule robustness was proposed to serve as surrogate criteria in the schedule instability cost minimization problem and buffer sizing.

In paper [1], I analyzed possibilities of applying the concepts of critical chain scheduling/critical chain project management (CCS/CCPM) and buffer management to construction scheduling. This approach was successfully tested by many production enterprises worldwide, and presented in many publications on project management. However, some weak points of this approach have been found:

- The method does not propose any optimization of the baseline schedule being the basis for buffer management. The way of assigning resources strongly affects the final form of the schedule and is thus deciding for the overall project duration (so the duration of the critical chain).
- The method's striving for minimal amount of work in progress by moving non-critical tasks to their latest acceptable dates may cause an unfavourable accumulation of expenditures and reduce chance for introducing corrective actions (such as repairs in case of bad workmanship or redesign in case of design errors).
- The method ignores other important optimization criteria such as minimizing cost of delaying particular activities with respect to their early starts.
- The method does not provide any empirical evidence for the way of estimating and reducing process duration; there is also no theoretical support for the method of buffer sizing (among others, the effect of parallel sub-critical paths on the size of feeding buffers is left without explanation)
- The method produces schedules that expire easily due to resource availability conflicts. Time buffers are represented as notional processes with no resource demand.
- There are no defined milestones for the processes – critical processes are required to start as soon as their predecessors are completed – this renders the contracting process difficult.

This critical analysis of CCS/CCPM and its buffer management approach was the starting point for a formulation of my own concept of improving the ways of determining the size of time buffers.

My first analyses on the methods of scheduling processes' early start in a way that makes them robust to disruptions were presented in [2]. As there are many rules of probabilistic task sequencing in the process of resource allocation, and there is a variety of task sequencing logic, I referred to Petri nets to plan projects involving repetitive tasks and allow for risk. My simulations presented in [2] were aimed at determining reliable start dates for subcontractors' commencement with works. I assumed that the scheduled date of a construction crew's commencement with works should be defined in a way that assures that the preceding crews have freed the working area after completing their tasks, and that the waiting time is minimized. Moreover, the way of scheduling these start dates should not reduce the probability of completing the whole project on time. Petri nets allow the user not only to conduct basic statistical analyzes such as finding the completion date at a predefined probability, but also to model resource usage and analyze their utilization rates. Thus, the dates of the crew's commencement with works were set on the basis of an analysis of their relationship with the project duration at a predefined level of reliability of completing the project on time, and the average number of days wasted as the crews' waiting time. However, this required a large number of simulations to be conducted, and information on the type and parameters of the processes' duration distribution. As construction projects are unique and many factors affect the work, it is generally difficult to access a sufficient quantity of historical records of duration of processes conducted in similar operating conditions to verify statistical hypotheses.

A probability density function of construction process duration clearly presents the risk profile and is defined on the basis of risk identification, analysis and assessment. In particular, quantitative analysis and assessment of risk is the most welcome input for the decision-making in risk management process, though obtaining reliable and objective data is a challenging task.

As it is difficult to define distribution type and parameters of factors affecting projects, one needs to resort to subjective experience, expert knowledge or intuitive reasoning. A rank order of risk factors is often based on ratios calculated as a product of estimated impact and frequency or probability of the factor's occurrence; it is a base for strategic planning of risk response, including risk reduction, to improve the potential benefits on the project and the chances of achieving project goals.

To identify factors that may affect duration of construction processes in Polish conditions, and to compare the factors with those quoted in the foreign literature on the subject, I conducted a survey. The literature review and direct interviews with construction managers provided an initial list of 63 risk factor and a survey questionnaire. The interviewees in the main survey were selected among the contractors' staff (chartered engineers) of companies active in Lublin region. The response to the survey was adequate for the purpose: 91 valid questionnaires were returned, so that a rank list of risk factors of greatest average impact of a risk event, of greatest average perceived probability of occurrence, and of greatest importance (or risk index, defined as the product of impact and probability) was prepared. To assess the level of agreement among the interviewees, the modified Kendall's coefficient of concordance was calculated. The results were presented in [5]. The analysis of results confirmed observations of other authors: the level of agreement on project risks ranking was low, but the sample was representative. As the personal experience of the interviewees vary, it would be wrong to assume the same importance of risk factors at different projects. The list of the most important factors – so the effect of the research – can be used as a tool facilitating identification of time-related risks as it provides a selection of factors in average case.

In [7], the risk factors were ranked according to their average importance: from the least to the most important. As the Gini coefficient was low (0,116), it was concluded that there is a low concentration of risk importance, and there is no small group of risk factors that would always have a considerable impact on process duration (in this respect, the Pareto rule does not hold). Therefore, the project duration risk assessment cannot be limited to the analysis of the most important factors while neglecting those less important.

Considering observations of Prof. K. M. Jaworski („the influence of particular risk factors is not constant and varies case by case – due to the fact that it depends on actual conditions and the particularities of a decision situation"[1]), and Prof. T. Kasprowicz (making business in construction „is strongly affected by internal and external circumstances"[2]), I assumed that the level of process duration risk is related with conditions specific to the project, the contractor involved and location/environment. Further literature review and interviews with practitioners (contractor's staff) conducted with co-authors enabled me to define 10 factors that characterize construction project conditions, and to measure their correlation with likelihood and impact of risk factors [7].

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[1] Jaworski K. M.: Metodologia projektowania realizacji budowy. Wydawnictwo Naukowe PWN Warszawa 1999

[2] Kasprowicz T.: Inżynieria przedsięwzięć budowlanych. Wydawnictwo i Zakład Poligrafii Instytutu Technologii Eksploatacji. Radom –Warszawa 2002

A major drawback of the risk assessment methods presented in the literature is resting upon individual opinions of a single expert. Thus, the reliability of assessment is questionable as being highly subjective. The proposed procedure of approaching duration risk in tight connection with a thorough analysis of project conditions done by a team of experts was presented in [7]. The importance of conditions (their impact on the duration risk level) is established by AHP – and the way of developing it by adjusting to naturally fuzzy input was presented in [4]. This modified AHP enables the user to aggregate relative preferences of experts expressed by fuzzy numbers. The vector of weights is defined by solving an optimization problem of preference programming. The method con be used to support group decisions as well as to express relative preferences as fuzzy numbers in terms of uncertainty of opinions. The assessment of project conditions and significance of particular conditions should be conducted for whole groups of processes – and the grouping is based upon similarities in susceptibility to particular conditions. The results of risk assessment provide input for building the risk response strategy. The presented way of risk assessment embrace all project conditions and do not limit the scope of analysis to the “most important” factors – they allow the user to account for cumulated (and considerable) effect of the secondary ones.

Normalized values of weights of all factors (criteria) can be established, in a limited way, also as geometric average on experts’ opinions. This approach guarantees that the Pareto optimality condition is met: a factor found most important by all experts should be of a greatest weight. However, this approach does not express the divergence of experts’ opinions, and can be used only in the case of low dispersion of opinions. The method of aggregating experts’ opinions put forward in [4] was initially applied to determining criteria weights in contractor selection problem, so it can be used to support decisions in tendering procedures and their initial stage of contractor prequalification aimed at minimizing the risk of wrong choice. This method allows for the actual scatter of experts’ opinions.

A procedure facilitating correction of distribution parameters of construction process duration (approached as random variable) with regard to previously defined project conditions and risk levels was put forward in [9]. If combined with computer simulations, it facilitates assessing susceptibility of the scheduled start dates to disruptions.

In the process of creating robust schedules, one needs to dispose of information on the scale of process duration variability with respect to random conditions. Durations of processes sensitive to disruptions can be approached as random variables. An assumption was made that the minimum and maximum durations can be defined in abstraction from the conditions of the considered project and that they may come from a database of completed projects (a contractor's in-house records). The mode of a process duration can be estimated as for the "average" conditions (risk level of 0.5) on the basis of experts' opinions or on median according to catalogued labour consumption rates.

A measure for the risk related with deciding on a particular value of a process duration was defined. To find the distribution parameters of a process duration at particular project conditions, an assumption was made that there exists a direct proportion between the measure of risk related with assuming a particular duration and the rating of project conditions (project risk level). It was also assumed that some corrections of reduction of maximum and mode estimates is possible at unfavourable conditions, or increase of minimum and mode – at favourable conditions should be possible for the planner. Nomograms helpful in determining parameters of triangular distribution of duration were provided for various ratings of project conditions; these were based on the least squares method. The triangular distribution may be used as a substitute for the actual distribution in the case that this actual distribution is impossible to define due to lack of enough number of historical data. The triangular distribution is simple and understandable for practitioners – it is also a good approximation of *beta* distribution used in PERT. However, this approach can be applied to other types of distribution.

Small standard deviation of residuals (below 0.136) and high determination coefficient (above 0.73 – greater than the boundary of 0.6 quoted in the literature on the subject) speak in favour of the model quality and validity of assumptions. Thus, the model can find a practical application.

This approach enables the user to account for the expected project conditions and their effect on construction process durations. It is also useful in planning risk mitigation strategy. Compared with PERT, the duration estimates are independent on project particularities and project-specific risks, which makes it possible to catalogue the estimates in databases for further use.

The method provides the user with input for Monte Carlo simulations and finding a value of process criticality. The process criticality is defined as a process' start date (and thus – project's schedule) susceptibility to disruptions. The critical processes understood this way require that som steps need to be taken to protect their start from being delayed – not only in the course of on-site operative management, but as early as at the works planning stage. The latter is done by means of time buffers).

A process' criticality is determined by the structure of the network model (the number of paths leading to the process, the number of the process' predecessors). The assessment of the effect of disruptions caused by variability of the train of preceding processes cannot be done on the basis of average on the delays of these predecessors with no account for possible deviation from expected values. Thus, an assumption was made that the process' criticality (in terms of meeting the deadlines) is contingent upon the scale of possible delay of the process' start relative to the start date defined in the baseline schedule. This approach implied that the procedure of assessing criticality must be integrated with duration risk assessment, assessment of process duration distribution, and Monte Carlo simulations.

The way of determining process criticality explained above was presented in paper [8]. The whole procedure comprises the following steps:

1. Calculating the minimum project duration and the earliest starts of all processes according to the initial baseline schedule created on the basis of expected values of process durations.
2. Conducting simulations on the network model with the assumption that process durations are random variables of predefined distribution parameters, and that the processes are started according to a predefined policy (e.g. no sooner than on predefined dates – early starts or fixed). The simulations are to find expected values and standard deviations of delays – deviations from as-planned starts.

The proposed measure of the process criticality is the value of process start delay such as the probability of the delay being greater than this value is lower than 0.1

regardless of the type of distribution and its parameters (the value is determined according to Chebyshev's inequality).

Processes that are more susceptible to disruptions and stronger affecting start dates of the processes to follow (so – the critical processes) should be assigned greater time buffers. The purpose of these buffers is to prevent propagation of disruptions in the schedule. The buffers take form of breaks (or idle times) between the earliest possible and planned start dates. Paper [8] puts forward a way of allocating and sizing these buffers. Buffers are sized on the basis of simulations and mathematical programming. A robust schedule with a deadline assures that the instability cost function is minimized; the instability cost is defined as a weighted sum of expected deviations of the scheduled starts and corresponding random values. The size of buffers in this approach is calculated according to the unit cost of delaying a process' start and the process' criticality determined in the steps presented previously. Despite the buffer sizes being the result of solving a mixed integer linear programming problem, the method is of a heuristic character. The adopted form of the objective function results from the author's striving for maximizing the surrogate measure of schedule robustness, and not directly the function of instability cost. The results obtained this way are considered at least adequate – this statement is supported by the results of verification tests. To improve the results, the author proposed a procedure for reducing sizes of buffers inserted at the ends of paths in the project network. This method facilitates finding better schedules – in terms of expected value of instability cost – if compared to simple heuristics that do not allow for variability of process durations.

The schedule *robustness* or its stability is measured by means of schedule instability cost – a weighted sum of absolute values of deviations of expected process starts from as-planned starts. As the robustness maximization problem of real-life cases is computationally complex, researchers attempt to find some surrogate measures of robustness. Therefore, in paper [10], I compared the surrogate measures presented in the literature on the subject, and put forward my own concept. Using an example, I compared quality of eight surrogate measures and the cost of schedule instability found by means of the adapted float factor heuristic. I attempted to modify the schedule in a way that each of the surogate measures of robustness was maximized, and in each case I found a corresponding value of schedule instability cost by means of simulation. The best surrogate measure of these considered proved to be this of my invention.

In [11], two further measures of schedule robustness were proposed to serve as optimization criteria for time buffer allocation. The form of these criteria enables the planner to use classic tools of linear programming. The measures' quality was assessed in a case problem for a number of predefined project times for completion. The results gave grounds for the following conclusions:

1. The value of the project's time for completion has a great impact on the project's instability cost (a hyperbolic relationship). Which of the measures of robustness is the most appropriate for the case (i.e. the one that leads to obtaining a schedule of the lowest instability cost), depends on the scale of time reserves allocated to the schedule in the form of buffers.
2. Lower values of schedule instability costs were obtained by means of the surrogate measure proposed in [8] – its application forced a better protection of processes at the ends of paths in network models. Buffers placed at intermediate points have higher schedule protection potential and are not so efficient in preventing propagation of disruptions.
3. All proposed measures belong to the same family of functions.

In attempt to reduce the schedule instability cost, one should therefore search for optimal (according to the criterion of time) baseline schedules – so that the overall float distributed as buffers could be increased. At this stage, one can resort to a variety of models and scheduling methods (such as resource assignment models, methods introducing soft logic, methods that optimize the order of locations in a repetitive task schedules, etc.); these were presented in papers [3, 6, 12, 13, 14]. As in the course of their application one determines the optimal sequence of processes (or locations for repetitive activities), precedence relations or processes modes, they should be also used in creating the robust schedule – by the network modification. Proposed models and methods are described below in detail.

Paper [3] puts forward a mathematical model of the project duration minimization problem with reduction of idle time (a bi-criteria optimization problem). Particular trains of processes whose continuity was to be assured were assigned additional dummy processes at the beginning and end of the trains; the processes were connected by arches with the beginning and the end of the project graph and with the beginning and the end of the considered train of processes. Each of these dummy processes was assigned a set of options of various non-zero durations and costs. Further it was assumed that reducing duration of a dummy process results in increase of cost by a unit. With this assumptions, the problem of reducing idle time of processes belonging to the particular trains is identical with the problem of maximizing the sum of durations of dummy processes or minimizing the sum of their costs. To find the non-dominated solutions of a bi-criteria problem (in the example), an evolutionary algorithm was used, and scalarizing of the objective function was done by means of Chebyshev's metrics.

Paper [13] considered the problem of selecting the ways for reduction of project duration and minimizing the cost of these measures. The mathematical model involved introducing additional "soft" relationships between processes – different than those used in the traditional scheduling methods. The precedence relationships represent technical constraints and organization of the works; these are defined as the network model is constructed and result from the logic of construction methods and resource allocation assumptions. In traditional methods, they are of fixed character. In practice, these relationships may be "hard" (actually fixed and impossible to change) or "soft" (the relationships that may be removed or reversed). If the sequence of processes is to be changed, additional processes may be required, and these involve money and time. However, to compensate for effects of schedule disruptions, softening the relationships may be better justified than changing methods to such that require less human effort or assigning more resources. Thus, the problem was modelled as a problem of selecting options from possible construction methods and/or softening some relationships (logical implications described by means of linear dependences) – and the objective was to minimize the total project cost and meeting a predefined deadline. Introduction of soft relationships increases the number of acceptable solutions for the problem of reduction of duration, increases the range of values of the optimization criterion, and enables the lower cost option to be found. From the point of project's economic efficiency, it is important for both the contractor and the client. The results obtained while solving a variety of model version for a simple schedule case, a following thesis was formulated: using soft precedence relationships improves flexibility of planning process times, resource assignment, resource levelling under the client's pressure to reduce project duration.

A model to facilitate negotiations between the general contractor and subcontractors was presented in [12]; it was aimed at allowing a schedule for minimal project duration to be developed and assure maximization of incentive bonuses paid to the members of coalition. The bonuses would be paid by the client for early completion. It was assumed that speeding up the works necessitated rescheduling and negotiations with suppliers and subcontractors. During the negotiation process, the bonus needs to be allocated; consideration was to be given to possible cost increase or decrease accompanying decreasing or increasing durations of processes. In this case, it was assumed that the relationship between process time and cost is linear. While defining the way of distributing the bonus to project participants, the authors used the concept of nucleolus, originating from the many-player game theory. Nucleolus is a distribution that assures levelling and reducing differences in the total value of payments for the game participants within any coalition and in full coalition that reduces, at the same time, the risk of breaking the full coalition and making another coalition by some of the game participants. Conclusion of a full coalition guarantees that total gains of all supply chain members are maximized. Small differences in payments – compared with the payments to be gained within other coalitions – discourage the players from entering them. The proposed model enables the early completion bonus (defined in a contract between the client and the general contractor) to be distributed to the greatest benefit, as well as the costs to be reduced by engaging less resources and allowing some tasks to take longer time.

Allocation of resources (such as workers, crews, subcontractors, machines, or machine sets), and synchronization of their activities are of key importance in terms of project time and cost. In [14] a model for harmonizing utilization of multi-skilled resources (resources able to do work that requires various skills) was proposed. It is a common practice, as construction workers are often trained in a number of trades and, if situation requires (e.g. effect of schedule disruption), are assigned tasks requiring skills other than these of their basic trade. The proposed decision model is to facilitate selection of such resources and synchronizing their work in terms of time – allowing for availability constraints due to the resources' duties with other tasks. The problem was modelled as linear mixed model with binary variables. The objective function minimized project duration within a predefined budget. The paper introduces an original formulation of resource availability constraints by introducing linear relationships that imply successive completion of processes assigned to the same resource.

Paper [6] presents decision models for minimizing duration of projects that involve construction of a number of buildings and target for resource work continuity. I put forward some methods of modelling additional constraints – including constraints that occur in an emergency or risk conditions; these methods allow the "travelling salesman" algorithms to be applied to scheduling. The method provides guidelines for selecting the unit (location) where the work should be completed first, accounting for predefined sequence in a subset of units, and allowing for constraints resulting from predefined time for completion of processes at particular units. In practice, prioritization of works to be conducted in a unit may result from economic reasons (doing most profitable job first, improving contractor's cash flows) or urgent need to satisfy expectations of the public (as in emergency). It may be necessary to do works in a subset of locations at predefined sequence because of technological reasons (such as in the case of tall buildings, where a location is a storey) or operational reasons (buildings to be completed and taken over by users in a sequence determined by a contract). Time constraints are usually defined in a contract. The proposed method of schedule optimization assuring continuity of works in locations that brings a permutation problem of task sequencing to a well-known "travelling salesman" problem has the advantage of availability of tools.

It is possible to implement the above presented models and methods of predictive scheduling by means of already existing and widely available software. However, my further research will involve preparing a bespoke computer application more comfortable in practical use.

The proactive approach to robust scheduling (so anticipating disturbances) is generally agreed to be more efficient than the reactive approach that consists in updating schedules as disturbances occur.

The proposed approach to project scheduling contributes to the development in the field of construction. Original scientific results of this research are as follows:

1) Implementing the concept of robust scheduling to construction:
   - Providing measures of schedule robustness and an algorithm of relatively low computational complexity.
   - Defining process criticality in risky environment.

— Supporting the decision making process at each stage of construction project risk management – thus, the methods are integrated.

2) Creating a method of risk level assessment that rests upon a thorough analysis of project conditions.
3) Creating a method for determining distribution parameters of process durations at various operating conditions; this is useful in simulation research and assessing the impact of schedule improvement measures.
4) Developing a fuzzy approach to AHP useful in group decision support in any field of construction problems; the approach improves objectivity of assessment and can be applied even if expert opinions are diverse.

The proposed way of allowing for risk in creating reliable schedules is argued to be efficient in protecting the project completion date, as well as stage or even process completion dates, against disruptions.

5. Other achievement in research

5.1. Publications prior to award of doctoral degree

My early research work focused around the following subjects:

— Considerations of ergonomics and environment protection in construction methods and management [A1, A3, A4, A6, A7, A8, A9, A10, A19, A22],
— Conceptual ergonomics, ergonomic design [A1, A2],
— Construction project management – virtual organizations [A15, A16, A17, A20, A21, A24, A26, A28],
— Construction enterprise management (strategic management, process management, evolution of corporate management structures) [A5, A13, A24, A26, A28],
— Construction project scheduling (application of *lean management* in project planning; evolutionary methods) [A25,A27],
— Construction logistics (logistic centres, minimizing logistic costs) [A11, A12, A14, A18, A23].

My major achievements of that time are as follows:

- Development of a method of assessing the design quality of flats for the disabled in terms of ergonomics [A1].
- Publication of a co-authored monograph [A1] summarizing the findings of research on ergonomics in living space and workspace design.
- Development of a method facilitating strategic planning of a construction enterprise based on key success factors and economic evaluation of rationalization measures aimed at improving competitive position [A5].
- Defining trends in the development of construction enterprise organizational structures [A13].
- Cooperation in the development of a project management concept based on the idea of virtual organization of a network structure [A21].

Prior to the award of doctoral degree, I published one co-authored monograph, 20 papers in Polish scientific journals, and presented 7 conference papers published in conference proceedings.

5.2. Doctoral dissertation

The title of my dissertation was: „The method of designing the structure of the construction project operating system".

The dissertation considers the design of the structure of the construction project operating system and scheduling construction projects of the "complex of operations" type. The system comprises a variety of the general contractor's organization units (e.g. the general contractor may be an enterprise of a network structure), and a number of co-operating external organizations – the subcontractors. The latter provide backup for the general contractor's own resources. The structure of this system – though set in advance while the project was being prepared for execution – is dynamic and develops with time. For the presented dissertation, it was assumed that the construction processes are of determined character. Availability of in-house resources (workforce, machines) is limited, but may be variable during project execution. Such decision situation was not investigated so far and thus there are no available solutions.

The proposed method of designing the structure of operating system can be used to support decisions in three following areas:

1) to decide if works should be done by in-house resources or subcontracted, and if so – to whom; this is the basic application of the method meant for supporting decisions at tendering stage,
2) to select independent contractors,
3) to assign in-house resources (such as teams and crews) or subcontractors at construction stage.

Assessment of viable options of configuring in-house and external resources was based on the following criteria affecting efficiency of the project and profitability of the general contractor:

- minimizing project duration,
- minimizing total cost of system's operations,
- minimizing cost of subcontracted works.

Main steps of the system designing method are as follows:

1. Preparation of input, so constructing a graph of technological relationships between processes (or work packages), preselection of potential subcontractors to assure quality of works, determination of process time and cost, determination of resource availability constraints.
2. Selection of best option – the structure of the system – supported by calculations by means of a computer system.
3. Verification of the solution – change of process dates within the existing floats.
4. Control of the construction phase – checks on conditions and times of the processes, and updating the model if necessary to adjust the system to changes.

As the exact methods cannot be applied due to computational complexity of the problem, and as heuristic methods are insufficient, I decided to search for the optimal solutions by means of metaheuristic methods adapted to the problem's particularities. The non-dominated solutions (from the point of optimization objectives) were generated using an objective function that scalarized achievement of the objectives. The function enabled a good representation of the whole set of non-dominated solutions to be found. It also allowed this complex problem to be reduced to a single-criterion optimization task. Selection of contractors was done by means of an evolutionary algorithm, and resource allocation by means of a dedicated heuristic algorithm for finding shortest project duration. This heuristics used another evolutionary algorithm to quantify process priorities. Selection of the final solution – so the system composed of selected in-house resources and subcontractors – is to be done by the decision maker by means of the R.E. Steuer's interactive algorithm or by analyzing the approximated relationship between the criteria values and their weights for the set of solutions that is an approximation of the set of non-dominated solutions.

Reliability of the method and the results was confirmed by verification tests based on test problems presented in the literature on the subject.

The proposed method, PSSWPB, is applicable in practice. It enables the user to check if subcontracting is economically justified, and how the options of the project delivery organization structure affect the project's efficiency and the project's outcome from the point of the general contractor. The method allows for many real-life specific constraints, which adds to its practical value.

In 2005, my doctoral dissertation was awarded a prize in the *Competition for the best student theses, doctoral and habilitation dissertations and scientific publications in architecture, construction, city planning, housing and municipal policies, construction economics, and facility management* organized by the Minister of Infrastructure.

5.3. Publications after the award of doctoral degree

My recent research was conducted in the following areas:

1. Logistics of construction projects and enterprises [B2, B5, B8, B17, B18, B20, B27, B28, B29, B32, B35, B49].
2. Models and methods in construction management [B3, B4, B6, B9, B10, B11, B12, B13, B14, B17, B21, B24, B25, B26, B33, B34, B46, B47].
3. Construction project scheduling [1 – 15, B1, B7, B15, B16, B19, B22, B23, B30, B31, B36, B37, B38, B39, B40, B41, B42, B43, B44, B45, B48, B50].

My main achievements in the first of the above mentioned areas are as follows:

— Developing a decision model for supplying a road construction site with aggregates [B2, B49]; the model was based on mixed binary integer programming, and allowed for Poland-specific constraints including: limited supply of aggregates, transportation problems (condition of roads that affects delivery times), possibility of advance payment – reimbursement of aggregate cost before the works requiring it are completed) being an incentive for the contractors to keep inventory. The model was an extension of the classic transshipment problem – modified by allowing for change of location of works (so the delivery targets change with the progress of works) at predefined time according to the schedule of works. The method allows the user to determine quantities of material to be delivered from suppliers (quarries) of limited production capacities to storage areas located along the route of a constructed road at minimum logistic cost.

- Applying reengineering rules to improve the logistic system of a ready mix concrete batching plant [B8]. The core elements of the logistic system were identified, and a set of changes to improve economic efficiency of the supply logistic system was proposed.
- Modifying the classic SWOT method to obtain quantitative results. The method enables the user to allocate the analyzed options in a four-field Grant Strategy Matrix; the options are regarded as points in a two-dimensional space. One of the dimensions represents the assessment of the external environment, the other – the organization's potential. The method was applied to assessing options of possible logistic systems to serve construction projects [B17, B18].
- Defining and describing the concept of *Supply Chain Management* (SCM) as a concept useful in managing construction projects [B20]. The relations among cooperating organizations were identified in terms of difference between the traditional and the SCM approaches. The SCM's benefits were listed together with barriers to its introduction to construction business. SCM is generally aimed at improving the client's satisfaction by reducing delivery times and overall service cost, not only in the field of supply logistics. SCM allows these aims to be achieved by optimizing resource flows within the supply network and coordinating efforts of the supply chain links in all fields of operation, and by partnering.
- Identifying a multi-criteria transportation problem in the supply logistics of linear construction projects. The problem consists in delivery of materials to storage areas located along the route of a constructed facility [B27, B28]. In many practical cases, the decision makers strive to take optimal decisions at a number of conflicting criteria (e.g. minimising: total transport cost, transport times, material

unavailability risk related with traffic in transport routes, and maximizing material quality). The problem was mathematically formulated and a method of solving it was proposed; the method was based on parameterisation of the set of non-dominated solutions by means of a substitute objective function that scalarizes the values of the criteria.

— Putting forward a cost optimization model for construction materials inventory management; the materials were to be used in a non-uniform way according to the schedule of works [B32]. The model allows for costs related with arranging and maintaining temporary storage areas, where the size of these areas is determined on the basis of highest level of inventory during the works.
— Publishing a co-authored monograph [B5] that summarised several years of investigations on supply chain management in construction. The monograph presented applications of the previously developed decision support models presented in [12, B2, B27, B28, B31, B32, B49].
— Developing a construction supplies planning model with consideration to uncertain (fuzzy) future prices of the material and to uncertain demand in consecutive periods [B35]. It is applicable to optimizing supplies and inventories on a project-by-project basis (on-site storage) as well as in the perspective of a construction enterprise with its project portfolios (central storage) . The problem was modelled as a fuzzy linear programming problem with fuzzy decision variables, to facilitate solving it, the model was transformed to a linear programming problem with three criterion functions.

My main achievements in the field of *Models and methods in construction management* are as follows:

— A co-authored monograph [B4]; it was published as a summary of several years of work of a research team; one of its leading subjects was application of the concept of virtual organization to develop management systems for construction projects. Some of these findings were published also in [B6, B13]. My individual contribution was, among others, a taxonomy and analysis of principles of organization structures design in construction enterprises, an analysis of changes and development of organization structure of a sample enterprise, a network model of a structure of a virtual organization created to complete a construction project, and a procedure of designing a project management system based on a model of a virtual organization (this was a team work with the co-author of the monograph), application of the concepts of process management and controlling to facilitate management of virtual organizations, analysis of logistic centres operations, a brief for a computer system to manage virtual organizations by identifying the requirements towards the system's structure and developing a matrix of relationships between selected processes within a virtual organization.

- Preparation of a taxonomy of methods and procedures used in the process of contractor selection for private and public construction projects [B9]. The paper presented results of research conducted in the course of preparing my doctoral dissertation.
- Programming and conducting simulation research on application of the *lean management* technique to realization of a group of multi-storey buildings and for prefabrication of floor slabs [B10]. The progress of construction works was presented as a complex model based on waiting line theory. Simulation tests were conducted in three stages, enabling a production plan to be created; the production plan assured completion of the project on time, prevented creating excess products inventories, assured full utilization of the production plant's capacity and continuity of the crew's work on the construction site.
- An analysis of results of a survey on procedures and criteria of subcontractor selection [B11]. The survey was conducted among large contractors. The paper presented results of research conducted in the course of preparing my doctoral dissertation.
- A framework for a construction enterprise management system on the basis of balanced scorecard at the stage of monitoring the implementation process and executing the enterprise's general strategy [B12]. A coherent set of rates for real-time assessment of the organization's performance and the level of achievement the organization's goals was developed.
- Development of a system of occupational risk management procedures for construction enterprises [B14] on the basis of a thorough review of regulations and methods of occupational risk assessment.
- Application of the Friedman's model to determining the contractor's mark-up and facilitating the contractor's bidding strategy [B21]. The proposed method, if

applied to the works pricing process, is to assure maximization of the expected value of contractor’s profit.

- Literature studies on Earned Value improvements [B24], assessing the potential of applying new tools to monitoring project performance against the baseline.
- Application of fuzzy AHP to weighting criteria for assessment of residential building’s usability on the basis of expert opinions [B25].
- Identification of basic criteria for assessment of orders potentially available to a contractor with regard to their profitability. A method facilitating the contractor’s decision making process in pricing the works as a whole and pricing particular items or contract elements was put forward; the objective is to maximize the net present value of project cash flows [B26].
- Development of a simulation model of cooperating machines of cyclic work; the model represented a road resurfacing project and was based on Cyclone network creation approach. The simulations were conducted to estimate cost of works and productivity for a number of options of machine set composition. The simulations allowed the best machine set to be selected with regard to a set of criteria under consideration (e.g. maximum output and lowest costs) [B33]. [B3] presented a way of modifying the waiting line model of machine sets operation that used results generated in simulations. This way, the sets could be arranged in a more efficient way.
- Identification and mathematical formulation of a problem of designing wall formwork [B34]. An example was used to test the model for two criteria of optimization. Wide selection of wall panels of various sizes in the systems offered in the market and possibility to use individual fitting timber for length adjustments facilitate applying the systems to any type of structures and shapes. This however means that the elements need to be selected on the case-by-case basis, and this decision may affect rental cost and amount of work of the formwork erecting team. A further assessment of various floor formwork systems, presented in [B49], provides also guidelines for scheduling in-situ concrete multi-storey buildings.

My main achievements in the field of *Construction project scheduling*, excluding the work related with the series of papers [1-15] described in section 4c, are as follows:

— Modification of the computer system developed in the course of preparing my doctoral dissertation by adjusting it to solving one criterion optimization of a schedule aimed at allocating resources of variable availability [B1, B40]. Moreover, [B1] presents a method of applying the aforementioned system to calculating total and free floats.
— A summary of research in the course of preparing my doctoral dissertation on designing the structure of the construction project operating system [B19].
— Modification of the computer system developed in the course of preparing my doctoral dissertation by adjusting it to solving a bi-criteria (time-cost) optimization problem aimed at allocating resources of variable availability and selection of best options of construction methods [B16, B41, B42].
— Analysis of applicability of evolutionary methods to construction project scheduling, being a continuation of my doctoral dissertation [B7].
— Mathematical formulation of a model of a resource total idle time minimization problem for schedules assuming continuity of works in locations [B15]. The solution – the optimal sequence of locations – is identical with the problem of finding the shortest Hamilton cycle; the cycle is to comprise all nodes of a graph (so all locations). Two algorithms were applied to find the solution – the Hungarian exact algorithm and a heuristics – to compare their practical availability.
— A critical analysis of PERT assumptions on distribution type and parameters of process durations, independence of process durations, and the method of analysing the network model in the function of time – with the method's effect on project duration estimates at assumed confidence level [B22, B45]. The analysis was illustrated by examples: a network model of a building refurbishment project was created and analyzed by means of PERT and Monte Carlo simulation. The results obtained by these two methods were compared to give grounds for conclusions on the reliability of assumptions.
— Application of variance reduction methods for more accurate estimates of project duration in Monte Carlo simulations of network models [B23, B30]. Preliminary analyses were made by using test network models to assess efficiency of selected methods of variance reduction: the LHS (Latin supercube sampling) and the Antithetic Variate Method [B23], and later Quasi-Monte Carlo and stratified sampling [B30].

- Development of a mathematical model for the problem of resource levelling that minimizes “peaks” in total employment [B31]. The analyzes prove that improving resource utilization rates is possible not only by shifting non-critical tasks between their early and late starts, but also by adjusting intensity of non-critical processes of secondary importance as they proceed.
- A proposal of analytic determination of time buffer sizes; the buffers are to protect the schedule against late availability of resources introduced to the project consisting of repetitive tasks at consecutive locations [B38, B50]. It was assumed that, like in PERT, process durations are random variables whose parameters are calculated on the basis of pessimistic, optimistic and most likely estimates.
- Modifying the assumptions of the classic assignment problem by allowing for options in the sequence of conducting processes: concurrently, in sequence and mixed, the latter modelled using network methods [B36]. The algorithms for solving the models were proposed to enable the user to apply them to practical construction scheduling problems.
- Constructing a mathematical model for scheduling repetitive processes conducted by work gangs in locations of non-uniform work quantities. The model was to be used for minimizing total project duration and assuring continuous resource utilization [B37]. As the optimization criteria are in conflict, the problem was considered as a bi-criteria optimization problem to search for trade-off solutions.

To summarize, after the award of the doctoral degree, I published:

- 2 co-authored monographs,
- 3 chapters in monographs (1 in English),
- 7 papers in JCR journals (+ 1 accepted for publication),
- 42 papers in other journals (of those, 14 in international in English and 28 in Polish journals), and
- 13 conference papers published in the form of conference proceedings (7 international and 6 Polish).

Published works are summarized in Table 1. The number of works without co-authors is shown in brackets.

Table 1. Summary of published works

No.	Type of work	Number of works before PhD degree	Number of works after receiving PhD degree			Total number
			Series	Other	Total	
1	Papers in JCR database	—	5 (1)	3	8 (1)	8 (1)
2	Monographs in Polish	1	—	2	2	3
3	Chapters in monographs in Polish	—	—	2 (1)	2 (1)	2 (1)
4	Chapters in monographs in English	—	1 (1)	—	1 (1)	1 (1)
5	Other papers in international journals in English	—	4	10 (1)	14 (1)	14 (1)
6	Papers in Polish	20 (7)	6 (1)	22 (4)	28 (5)	48 (12)
7	Papers in proceedings of international conferences	1	—	7 (1)	7(1)	8(1)
8	Papers in proceedings of other conferences	6 (1)	—	6	6	12 (1)
9	Total number	28 (8)	16 (3)	52 (7)	68 (10)	96 (18)

Table 2. Works included in Web of Science database

No.	Journal / proceedings	Symbol of work	Year	Impact factor	MS&HE score (2014)
1	Journal of Business Economics and Management	2	2008	3.866	25
2	Automation in Construction	4	2010	1.311	40
3	Technological and Economic Development of Economy	8	2011	5.605	35
4	Technological and Economic Development of Economy	13	2012	3.224	35
5	Eksploatacja i Niezawodność – Maintenance and Reliability	15	2015	0.505	15
6	Journal of Construction Engineering and Management	B1	2006	0.676	25
7	Inzinerine Ekonomika – Engineering Economics	B2	2014	0.972	20
8	Baltic Journal of Roads and Bridge Engineering (accepted)	B3	2015	1.053	25
9	Procedia – Social and Behavioral Sciences	B27	2012	–	10
10	8th International Conference Modern Building Materials, Structures and Techniques, 19–21 May 2004, Vilnius, Lithuania, p. 199–209 (proceedings)	B40	2004	–	10
			Total	17.212	240

A total impact factor of my publications, according to the Web of Science (Table 2), is 16.159 (+ 1.053 paper accepted for publication), the number of citations is 56, and h-index is 4. According to Scopus, the number of citations is 100, and h-index 5. According to Google Scholar, the number of citations is 246, and h-index is 7.

5.4. Other achievements

The results of my research were disseminated also in the form of conference papers and presentations. Prior the award of the doctoral degree, I participated in six scientific conferences in Poland, and after the award of the degree – in six conferences in Poland and 10 international congresses.

In 2009-2011, I was the manager of a research project "Designing robust construction schedules with multi-attribute assessment of the impact of operating conditions"; the project was sponsored by the Polish Ministry of Science and Higher Education – grant no. N N506 254637.

I was also the general contractor of the research project No. 7 T07E 011 17 „Application of the concept of virtual organization in the development of the construction project management system" (grant by Polish Scientific Research Committee (KBN); 2000, project manager: Anna Sobotka).

In the years 2011-2013, I was the contractor in the research project No. N N506 212440 „Applying the concept of Supply Chain Management to road projects (grant by the Polish National Science Centre (NCN), project manager: Anna Sobotka).

The work related with the above grants involved my active cooperation and a one-week placement at the Zentrum für Logistik und Unternehmensplanung in Berlin, Germany (Prof. H. Baumgarten) and Rostock University, Germany (Department in Wismar; Fachbereich Bauingenieurwesen, Institut für Bauwirtschaft und Baubetrieb; Prof. Dr. habil. W. Schäfer) in 2000.

I also cooperate with the School of Environment and Technology, Faculty of Science and Engineering, University of Brighton – a two-weeks placement in 2011 that produced a co-authored paper.

I am the member of the following scientific associations:

- EURO *'Association of European Operational Research Societies'* (within IFORS, the *'International Federation of Operational Research Societies')*; EURO Working Group OR in Sustainable Development and Civil Engineering.
- Gnedenko e-Forum (International Group on Reliability).
- Section of Construction Project Engineering of the Committee of Civil Engineering, the Polish Academy of Science (since 2007).

I cooperate with numerous scientific journals as a reviewer. So far, I have reviewed 16 scientific papers for journals indexed in the Journal Citations Reports (Journal of Civil Engineering and Management, Technological and Economic Development of Economy, International Journal of Computational Intelligence Systems, Journal of Intelligent and Fuzzy Systems, International Journal of Civil Engineering). Additionally, I reviewed five papers for the Journal of Civil Engineering and Architecture (ISSN 1899-0665), and one paper for Archives of Civil Engineering (ISSN 1230-2945).

My awards and recognition for achievement in science include, in order of time:

- Recognition by the Chief Labour Inspector (National Labour Inspectorate) in the competition for best publications on occupational health and safety for a co-authored monograph "Ergonomics in construction", 1999.
- Team Award of the Minister of Infrastructure for a co-authored book „Management in construction. Organisations, processes, methods" (19th April IV 2004).
- Award of the Minister of Infrastructure for the doctoral dissertation "The method of designing the structure of the construction project operating system" (22nd April 2005).
- Team Award of the Minister of Infrastructure for a co-authored book "Methods and Models in construction project engineering" (12th May 2008 r.).
- Second Grade Award of the Rector of Politechnika Lubelska for achievement in science (1st October 2004).

- Second Grade Individual Award of the Rector of Politechnika Lubelska for achievement in science (1st October 2006).
- Second Grade Team Award of the Rector of Politechnika Lubelska for achievement in science (1st October 2013).