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SUSTAINABLE MANAGEMENT OF CONSTRUCTION LABOUR

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ABSTRACT

The construction industry of Estonia has experienced a period of economic growth which has started to turn down for now and the output forecasts state that this recess will continue. While the availability of unskilled workforce will be growing, the lack of high quality skills in the labour market is becoming even more acute when, after joining EU, skilled construction craftsmen have a choice of leaving to better paid European countries. Purpose of the research is to improve management strategies, decrease the mismatch between required and available skilled labour and to discuss the consequences of ignoring the interests of craftsmen. Without quantitative estimations it is impossible to persuade contractors to invest in workers. A simulation model reflecting the performance of a construction firm is introduced. It enables to evaluate different management strategies considering contradictive interests of owners, contractors and craftsmen in purpose to find a compromise between them.

KEYWORDS

Sustainability, labour management strategies, simulation modelling, multiskilling, workforce

1. PROBLEM RECOGNITION

Construction is a labour intensive as well as craft-based activity and the behaviour of people has an enormous influence upon the organisation and performance of construction firms. Sustainable development of construction industry has to concentrate not only on sustainable building technologies and construction materials but also on respectful and considerate labour management strategies. Workforce has to be treated as the most valuable un-reproducible resource with vulnerable and hardly predictable behaviour.

Our previous research [1] and the literature reveal a number of factors which have combined to influence the construction skills shortfall. Some of these include:

- the introduction of **new technologies** which have reconstituted the skills required [2–4];
- the **growth in self-employment** and the use of labour-only sub-contractors which have reduced the commitment and investment in training

within the industry [5–8]. Self-employed craftsmen, in turn, are not able to handle their qualification improvement issues and there is a direct correlation between the fall of trainee numbers and the numbers of self-employed [9–11];
- the **poor image of the industry** which unfavourably affects its popularity as a career choice [3, 12, 13]. The image is low among workers themselves as the majority of construction crafts workers of various ages and experience would never recommend their trade to their children [14];
- **high mobility** of construction workers as the result of unattractive image, unsafe work place, irregularity of the workload, lack of respect and opportunities for training;
- the **dissatisfaction with labour organisation**, especially the unstable workload has been mentioned as the reason of release by relieved workers [15-17];
- the **site safety and quality of works** are always the least and the last to be attended to, as they are always the conflicting goals running in different directions to „earning“ and „speed“ [18-20];
- a set of problems related with issues of **women in construction** deserve a special attention of researchers [21–23];
- **globalisation** has added also negative ethnic characterisation and therefore consideration of **cultural differences** of multi-lingual construction teams is very important [24–27];
- since joining EU the Eastern European countries have to face a fact of **drain of workforce** to better paid countries.

The combination of these factors has led to a labour market reliant upon a casual workforce, incorporating high levels of self-employment, low levels of training investment and hence, low quality skills [12, 28, 29].

The ways construction work is planned, scheduled, and controlled have direct bearings on workers' motivation and general satisfaction. Unfortunately only a relatively small number of studies dealing with construction craft workers exist if compared to construction materials and technologies. Taking described situation into consideration we cannot underestimate the necessity of research of construction workforce, because when compared to other strands of construction research in this area is largely undermined [30].

1.1. Goals and Hypothesis

Improvement of construction management cannot be an abstraction: it could be better quality, new materials, modern machinery, lower price, higher speed, skilled workforce etc. If the analysis of current situation and best practice of other countries allows making improvement suggestions and could be considered as the foundation of research then for principal improvement we need a quantitative evaluation of these changes. Management is always a question of interests, moreover, a contradiction of interests of different parties. We could point up at least three parties involved in construction:
- Client, interested in high quality buildings as fast and as cheap as possible;
- Contractor as service provider, keeping an eye on the stability of orders portfolio, high profit and less expenses
- Craftsman, interested in a stable workload, satisfactory and safe working conditions and a fair salary.

This research concentrates on finding a compromise between these parties and presenting a simulation system, which would demonstrate by quantitative estimations that the welfare of craftsmen is in the best interests of both the client and the contractor. Improvement of the organisation takes not only less capital investment as compared to modernising technical equipment, but it also solves the human resource problem – satisfaction with work. It is important to develop a sustainable attitude towards construction labour among the decision-makers.

1.2. Research Methods and Strategy

The adoption of a management strategy should be based on an economic calculation rather that intuitional reasoning. It means that we need an evaluation tool for the estimation of different management strategies consisting of a set of controversial goals. Mathematical methods of economic theory provide mostly qualitative answers: whether the revenue will rise or fall if we change variables, but also quantitative answers for particular decisions. We look for a quantitative evaluation in the present approach of the management strategy, not a single specific managerial decision.

Methods of simulation modelling enable to simulate, without interfering into the real production process, various different construction situations caused by different strategies. The creation of a simulation system that would adequately reflect the performance of a construction firm is most complicated as it has to include the description of production and economic activities with all conflicting restrictions involved.

2. MAIN TENDENCIES OF CONSTRUCTION WORKERS' SPECIALISATION

The profession of a construction craftsman is not highly valued at present, which in turn has a negative impact on the quality of construction works. The general reason for low value lies in dissatisfactory labour conditions and management strategies. Many researches have tried to bring attention to these problems [3, 5, 12, 14, 24, 31-40].

The ways construction work is planned, scheduled, and controlled have direct bearings on workers' motivation and general satisfaction. Unattractive image, unsafe work place, lack of respect and opportunities for training lead to high mobility of construction workers and irregularity of the workload favours the fluctuation of the personnel. From 10 to 22 % of the relieved workers mention the dissatisfaction with labour organisation, especially the unstable workload, as the reason of their release [16]. Every percent of increase in the fluctuation of personnel will in turn reduce the realisation of construction programme. Skill levels continue to decline while owners squeeze contractors for lower costs and faster schedules through the low-bid delivery process. In response, contractors have reduced training and use less skilled craftspeople to be competitive [29]. Considering the safety issues involved in being in the construction field, it is no wonder that many are opting to pursue other careers.

The coordination of work of every employee in terms of time and space is a daily issue in any construction firm. Consequently, the creation of rational forms of cooperation and distribution for workers is one of the most important issues of labour division in building enterprises. The main productive unit is a labour team (crew) consisting of workers of particular trades. By large scale it is possible to draw out two opposite labour division strategies: single-skilling, where workers master one specific craft trade and multiskilling, where a craftsman is able to perform several trades. Both of them have their strong and weak sides.

2.1. Single Skilled Craftsmen

Pro: Such teams achieve high productivity and workers can raise their qualification level easier as same operations are frequently repeated. Therefore, the higher the level of specialisation is the higher quality of work and better results in productivity can be achieved by the team. The fact that normally there are several specialised teams on the building site at the same time, requires very exact coordination of their work in terms of time and space.

Contra: Narrow specialisation can be effective only if all workers are provided with work, otherwise the efficiency falls and even yields opposite results because "for single-skilled workers, the work should be broken into small pieces, each piece or task involving a single skill", which makes the scheduling process very complicated, or even impossible for smaller companies [16]. The division of the workers between a large number of building sites leads to the deviation from a rational technological order of works, fluctuation of workload and consequently the labour productivity of the team can fall dramatically.

The efficiency of specialisation is primarily guaranteed by the necessary quantity of work. Consequently, the stable and uninterrupted workload is possible in sufficiently large firms and at high concentration of buildings under construction.

2.2. Multiskilled Craftsmen

Pro: The researches reveal that the benefits of multiskilling are labour cost savings and fewer workers needed; it also enables increase in average employment duration and of earning potential for multiskilled construction workers. The research in Germany and Netherlands showed that broadly skilled and adaptable labour force accords well with the higher levels of technical complexity of the construction processes [41]. The effectiveness of multiskilling has been declared in several research works on labour resources and also in practical experience [16, 20, 42-46]. Multiskilling makes workers more competitive, because workers stay longer on a project and more flexible utilization is possible including more unforeseen maintenance activities, because multiskilled workers and crews have a broader variety of skills. When multiskilled workforce is utilized properly, it should generate savings, because of lower turnover rates, higher productivity, and fewer accidents [47].

Contra: From an opposite perspective, we have to be aware of possible consequences of multiskilling as drop of average efficiency about 15% [46, 48] and agree that endless mastering of additional skills cannot be reasonable and might lead to the opposite results [41].

2.3. Subcontracting versus Training

The last decades show a decreasing tendency of the amount of work accomplished by a main contractor up to passing all the work over to subcontractors. Craft workers are hired for a specific job and laid off at the completion of the project, this shows a lack of concern for an individual and a need of individual improvement. In this situation only a main contractor fulfils a project management function. There are two major reasons which cause the above mentioned changes. First, a main contractor trying to complete the majority of construction works with its own labour has to face unproductive expenses connected with unstable workload but also irregular orders portfolio. Dismissal of workers is an option in order to reduce unproductive expenses. The second reason is connected with the owner. In laissez-faire construction market the owner's revenue depends on the duration of the construction and this is why owners continuously push contractors to shorten the length of the construction period, which in turn extends the problem of unstable workload.

The main contractors have solved the problem of unstable workload by decreasing the amount of their own labour up to abandoning it completely. Virtually all labour is hired only when immediately required and laid off as soon as workloads fall. It brings along the increase of general undermining of collective wages, social protection, and industrial relations in favour of work contracts or task works, casual employment and agency labour or, at the professional level, domestic work and freelance employment [6, 8].

But eliminating one problem a new one arises: the growth in only sub-contracting and self-employment has led to a decline in training, and there is a direct correlation between the fall of trainee numbers and the numbers of self-employed. Eventually the skills of workers are not developing because it is very seldom that formal training is provided by labour only subcontractors or the self-employed themselves because of insufficient facilities, the funds or the will for training of mentioned groups [9, 11]. While vocational training system ignores the real needs of construction market this unquestionably works against the well being of the industry.

It will be hard to find anyone who would claim that the training of skills or qualification improvement is useless, but when it comes to finding time or money for that the attitude is not so favourable. Investing in workforce should be supported by knowledge that it really pays off and yields measurable profit. In this research we try to find a compromise between the interests of different parties and raise their motivation to improve the competence management of construction craftsmen which eventually will serve for the welfare of the whole construction industry.

3. CONSTRUCTION PROGRAMME VERSUS CRAFTSMEN COMPOSITION BY TRADES

It is inevitable and intrinsic to the building technology that it is almost impossible to provide an even workload for all workers of different trades on the building site during the whole construction [5, 6, 20, 29, 45, 46, 48]. We wondered how deep the described problem might be and started to explore the extent of the differences between main contracting companies depending on the type of buildings constructed by them. It turned out that main contractors always face labour management problems no matter the type of a building constructed [49, 50]. The efficiency of a construction firm working in a multiproject environment depends on the construction duration of every single project and the intensity of its resource usage. Contractors have to vary the amount of labour applied to an activity depending on the amount of work available [45]. The task of shortening the length of construction period and providing an even workload to all craftsmen of different trades are controversial as the improvement in the first factor leads to the worsening of the second and vice versa [51, 52].

One of contractors' arguments as to why they give up their own workforce and prefer to work on subcontracting basis is that their orders portfolio and construction programme are unstable. The study of typical labour resource histograms can indicate which combinations of skills are most preferable and in compliance with schedule demands [16].

We have conducted a detailed survey where construction projects in 25 firms were monitored during 5 years. We wanted to know if the construction programme is stable enough to provide craftsmen with permanent work. High values of standard deviations lead us to the conclusion that the distribution of building types in construction firms is of a random character; contractors are forced to accept all offers due to heavy competition. Distribution of craftsmen by trades in the same construction firms and during the same period was also chaotic. Next step was to estimate the severity of the situation and find an answer to the question: How significant is the impact of a construction programme on the composition in craftsmen by trades? The results obtained from the research on the structure of works in different building types were encouraging: no matter how changeable a construction programme is, the requirements in professional composition are rather stable and consequently an unstable construction programme should not be used as an excuse for rejecting construction craftsmen. However, the need for different trades was constant only on the average during the planning period whereas at different time intervals overloads and slack times were unavoidable while single-skilled craftsmen were hired. This leads to the conclusion that a certain amount of craftsmen can be successfully used as the firm's own workforce if they are multiskilled workers. The number of combined trades and their reasonable combinations remains open.

4. SIMULATION MODELLING OF CONSTRUCTION FIRM PERFORMANCE

The simulation techniques enable to compare the efficiency of several alternative solutions without intervention into real construction process. The major problem of simulation modelling is the adequacy of modelled objects. This will be a key factor when wider conclusions on real systems are being drawn.

The performance of a construction firm is modelled as a network of schedules (a multi-project system), detailed up to the level of resource usage (labour, building materials, machinery, finances). Economic assessments are derived from profit formation (resources and projects) in the form of relative assessments of the most profitable simulation version of the firm. The management strategies are modelled as resource restrictions (amount, treatment), project restrictions (duration, deadlines, and succession) and necessary cost additions for different management strategies.

The initial simulation model for evaluating different management strategies in construction was created by Prof. J. Sutt where the possibility of creating sensitive models and computer software for such kind of investigations was proved [49, 52]. His main focus at that time was the influence of construction duration. Further the simulation system was developed for evaluation of labour management strategies and especially the efficiency of multiskilling [1, 52, 53]. On the basis of named investigations the system of models was created, which could be modified and reconstructed in purpose to evaluate the efficiency of investments in construction workforce. The simulation model has been constantly modified with relevant changes and reconstructed in purpose to enable the evaluation of economic efficiency of investments in construction workforce. A comprehensive description of the research methodology may be found in previously named research works, and therefore only an overview is now presented.

The entire model is based on the concept of a firm that simultaneously works on a variety of construction projects**.** The structure of a simulation system consists of a set of five linked sub-models as shown in ***Figure 1***.

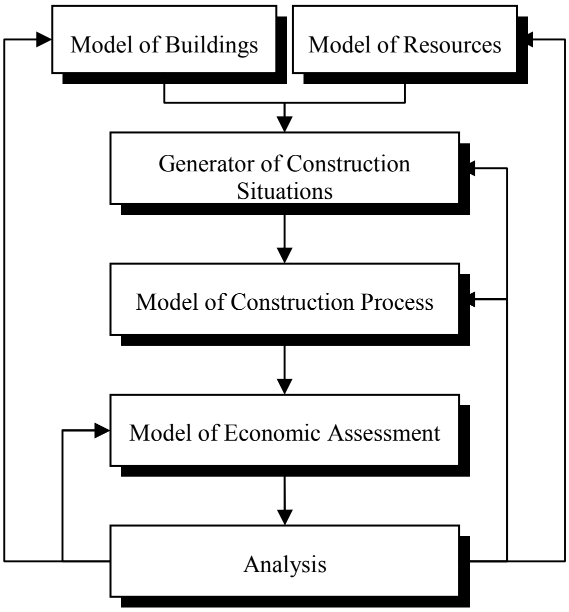

Figure 1 Principle structure of the simulation system

The organisational and technological conditions of a construction process are taken into account in the *model of buildings* in the form of networks. The resource parameters of a company (labour resources, building machinery, finances) are considered within the *model of resources*. Different construction situations are created by using the *generator of construction situations* and by changing the parameters in the model of buildings and in the model of resources. These can be simultaneously explored within the overall simulation system. Treating the *model of construction process* as a separate block in the simulation system enables to take an interactive part in the modelling analysis, which makes the accuracy of the process within the model more adequate. The *model of economic assessment* represents the objective function of the activities of the building enterprise. The cost function determines a set of fines and bonuses if the actual state of any of the system elements differs from the planned ones. In the current use we look for economic assessments which represent the interests of a contractor (E') and of the client (E'') – only then when the interests of a client are balanced with the interests of a contractor and the interests of a contractor are balanced with the interests of a craftsman, it would be possible to make a final decision how effective the multiskilling is.

The central problem in this research is to find out if and how the contractor's profit is influenced by different ways of combining trades among workers. In this approach, the variables are the number of combined trades assigned for a worker and different ways of combining trades to create multiskilled workers while the general quantity of labour remains constant. The workers' specialisation by trades corresponds to the Models of Buildings presented in a form of network schedules where works are detailed up to every single-skilled trade. This requires the aggregation of the topology of the network regarding the trades used. In the simulation process, the topological aggregation automatically changes according to varying schedules of compliance between the activities and trades.

The efficiency of combining trades is investigated on the basis of detailed building situations, modelled as a multi-project time-schedule of the construction firm and considering the respective changes in the Model of Buildings and the Model of Resources. The efficiency of the performance of a construction firm depends on two aspects of the building process modelled in the form of a time-schedule:

- *Duration*: the difference between the planned construction duration of each building and the obtained one at simulation leads either to fines (if the modelled period exceeds the planned one) or bonuses (if the modelled period is shorter);
- *Intensity*: the parameters characterising the use of limited labour resources (idle time or overloads, the frequency of transferring workers from one building site to another etc).

The efficiency assessments are calculated separately for the contractor E' and for the client E''. The use of multi-skilled workers is characterised by the number of combined trades - n. For every value of n, three different ways of combining trades were modelled.

For the contractor, using multiskilled workers influences the construction cost price through changes in seven of its components. The first three components are related to direct labour costs and reflect the uniformity of the workload. The changes of the construction cost price are caused either by idle time (E_1'), overloading (E_2') or changes in costs connected with transferring workers from one building site to another (E_3'). The remaining four components of the cost price reflect the changes in the length of the construction period caused by the changes in the use of labour. These include the changes in the costs of using building machinery (E_4'), expenses on temporary buildings (E_5'), costs of keeping the street section and building site in good order (E_6') and the costs of loan interests (E_7').

In order to evaluate the efficiency of multiskilling from the client's standpoint, the analysis of E'' is based on an economic assessment determined by changes in the length of the construction period. These include changes in the potential profit due to shortening or prolonging the time at which the building can come into use - E_1'' and interest charges on loans - E_2''. The interests of a contractor are determined through the potential revenue of a client. To be more exact, E' is a function of expenses and E'' a function of potential revenue revealed through the profit of a client. As regards the interests of a client, normally the quantity of production per time unit is considered. In project management we cannot use the same categories, so the intensity of production is evaluated through the relative duration, i.e. the ratio of the real length of construction period to the technological minimum length.

The number of combined trades and their combinations are the guided parameters in the simulation experiment. Efficiency assessments are calculated for every value of these parameters.

5. RESULTS OF SIMULATION

The purpose of this simulation experiment is to evaluate various labour usage strategies in order to find management solutions for chosen priorities. Quantitative assessments of cost and revenue functions are based on the simulation of a construction process and economic activities of an average construction firm erecting buildings of different structural and functional groups.

The results of experiments showed, that the efficiency depends on the number of trades while the impact of different combinations of multiskilling was insignificant. Thus in the further analysis of the experiment we are going to represent the changes of economic assessments caused by the multiplying of trades only whereas the details of combinations (which trades are combined) will be ignored.

The aim of the chosen strategy of construction management is to ensure the accomplishment of modelled works with maximum intensity so that every building could be finished within estimated construction duration T^N; it is the first priority over workload stability. As there is a shortage of available resources the changes of intensity (like idle periods and working overtime) are allowed. The available number of workers by trades established in the restrictions can be ignored in cases where there is no time left for the particular work. As the length of the construction period and also the buildings under construction are very different, we have to use a relative duration as a measuring unit. The benchmark for a relative length of construction period could be the construction duration T^N. If we name the construction duration of a particular project obtained during the simulation as T^F, the relative duration can be expressed as a ratio $\left(\frac{T^F}{T^N}\right)$ (Figure 2).

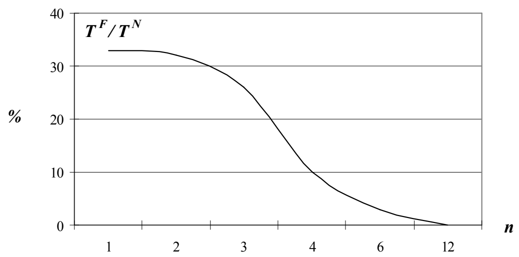

Figure 2 Dependence of construction duration on the number of combined trades

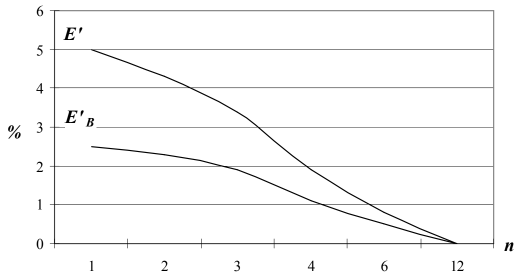

Figure 3 Dependence of cost price on the number of combined trades

Using multiskilled workers makes it possible to shorten the relative construction duration approximately by 30 %. However, it is obvious from the dynamics of the function $\left(\frac{T^F}{T^N}\right)$ that the maximum shortening (20 %) is achieved by multiplying the number of combined trades up to 4, while assigning only 2 or more than 4 trades changes the duration assessment for about 5 % only.

The number of combined trades affects the construction cost price through the respective changes of its components, reflecting the uniformity of workload E'_1, E'_2, E'_3 and the economic assessments determined through the changes of construction duration E'_4, E'_5, E'_6, E'_7.

In *Figure 3* the summary curves of these components are displayed. $E' = \sum_{i=1}^{7} E_i$ reflects the changes of the construction cost price for the contractor with no buffer buildings in the plan, which means that E'_1 has also been taken into account and craftsmen are paid for idle periods. $E'_B = \sum_{i=2}^{7} E_i$ represents the changes of the cost price of those construction firms who have included the buffer buildings into their programme, which means that E'_1 is not taken into account.

The analysis of E' dynamics shows that the maximum changes of cost price occur when the number of combined trades rises up to four whereas the cost price falls respectively by 3 % (with no buffer buildings in the plan) and by 1.5 % (with them). The further assigning of trades decreases the cost price approximately 2 %. This fact should be taken into consideration when the incentive system of multiskilling will be established. Similar results have been obtained by [42] who concluded "that benefits of multiskilling become marginal after acquiring competency in two or three crafts".

With the purpose to evaluate the efficiency from the client's perspective the analysis of E'' behaviour was accomplished. The contractor's interests are expressed through the client's potential revenue that is influenced by the change of construction duration caused by multiskilling. E''_1 represents respectively the changes of potential revenue from industrial buildings and E''_2 from holding the investments in non-industrial buildings. From the client's viewpoint it would be most profitable to have workers with wide profile because this allows the minimum construction duration. But the dynamics of graph E'' lead to conclude that the essential effect is achieved by raising the number of combined trades up to 4 (about 7 %). The effect from rising of the number of assigned trades any further is less significant.

5.1. Interpretation of Results

Could there be a solution satisfying all the parties – the contractor, the owner and the craftsmen? To find an answer we studied both the owner's revenue function E'' and the curve of contractor's cost price E' linking them to each other in *Figure 4*.

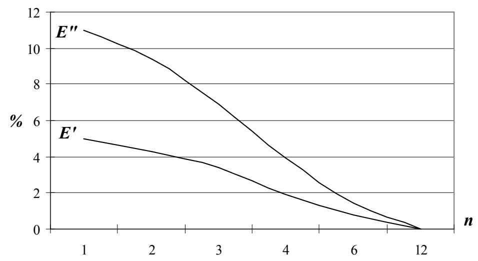

Figure 4 Summary functions of contractor's costs (E') and owner's revenue (E").

The results of the simulation experiment show that the costs of a construction firm increase by 5 % compared to the most favourable solution. It is clear that the contractor's costs connected with multiskilling should be reflected in the construction cost price. If the respective growth of the owner's summary revenue E" is higher than E, then there are both – means and interest. To escalate the contractor's interest in multiskilling it would be fair to negotiate that the owner should give up a part of the remaining profit for the incentive of the contractor. The most effective stimulation is dividing the profit 50:50. In that case, these compensations would be as effective as reasonable.

The results of the simulation modelling proved that the interests of the contractor and the client in multiskilling are obvious. Consequently, there is a need to find a way how to make the construction craftsmen interested in multiskilling as well. One way could be to cover the training and certification expenses for the craftsmen. But considering the practice where more and more firms prefer not to tie themselves with permanent workforce and the feeling of uncertainty that certified craftsmen would choose to leave to competitors, it would be difficult to convince contractors to make uncertain investments. Another option is that craftsmen themselves start investing in their knowledge. Yet they have to be sure that their effort will be appreciated in monetary terms and they will be paid remarkably better after learning additional skills.

We can suggest a particular sum of profit for multiskilling bonus. The size of the bonus fund could be 50 % of the potential reduction of cost price, attained as a result of multiskilling (see ***Figure 4***). Let us name it conditionally a multiskilling fund - MF and it could be calculated as follows:

$$MF = \Phi \times C \tag{1}$$

where Φ - ratio considering the efficiency of multiskilling and C - estimated total cost of works in the planning period. The money from this fund can be divided between the craftsmen through the ratio depending on the number of combined trades λ as follows: craftsmen combining two trades – λ_2 = 20 %; craftsmen combining three trades – λ_3 = 30 %; craftsmen combining more than three trades λ_4 = 50 %. The suggested distribution corresponds to the efficiency curve of multiskilling where the most significant part of the effect was attained by raising the number of combined trades up to 4, while combining more trades was economically not reasonable (see *Figure 4*). The calculation of supplementary payments q_2, q_3, q_4 for multiskilling depending on the number of combined trades is suggested below:

$$q_2 = \frac{\lambda_2 \times MF}{\lambda_2 \times N_2 + \lambda_3 \times N_3 + \lambda_4 \times N_4} \tag{2}$$

$$q_3 = \frac{\lambda_3 \times MF}{\lambda_2 \times N_2 + \lambda_3 \times N_3 + \lambda_4 \times N_4} \tag{3}$$

$$q_4 = \frac{\lambda_4 \times MF}{\lambda_2 \times N_2 + \lambda_3 \times N_3 + \lambda_4 \times N_4} \tag{4}$$

6. CONCLUSIONS

The statistical analysis of the internal structure of works by buildings under construction leads to the conclusion that no matter how changeable a construction programme is, the need for workers' composition by trades is rather stable if the contractor could use multiskilled workers. However, for single-skilled craftsmen overloads and slack periods would be unavoidable. It would be reasonable to keep a multiskilled team on a permanent basis and motivate craftsmen in their qualification improvement. It will improve the quality of work, but also raise the workers' loyalty towards their employer.

A simulation system was created in order to estimate the efficiency of multiskilling. The simulation system enables to evaluate the quantitative economic assessments on combining the trades. We learned from the simulation experiment that multiskilling decreases the construction cost price through improved workload and the respective shortening of the construction duration as a result of it. We can bring out the following:

- Using multi-skilled workers makes it possible to shorten the relative construction duration by approximately 20 % due to a more uniform and full workload for craftsmen.
- Combining four trades decreases the cost price around 3 % and increases the potential revenue of a client approximately by 7 %. The influence of combining more than four trades is insignificant as is the effect of using different specific combinations of trades. The analysis of the efficiency assessments from the aspect of a construction firm and client reveals that both of them are interested in multiskilled craftsmen, which indicates that it would be worthwhile to pay workers also for the additional skills they have acquired.
- Including some buffer buildings into the construction programme improves the arrangement of labour resources. The needed quantities of works on the buffer buildings are about 16% from the total cost on the main buildings under construction. The more multiskilled craftsmen are involved the less buffer buildings are needed.

The simulation experiment proved that multiskilling should interest both the contractor and client. Consequently, there is a need to find a way how to stimulate craftsmen. A simple stimulation system is suggested for motivating craftsmen: a construction firm should give 50 % of the effect from multiskilling to a respective incentive fund. The money from this fund could be divided between the craftsmen depending on the number of combined trades and regarding the efficiency curve of multiskilling. In this way the compensation for multiskilling will be high enough to motivate craftsmen learning additional skills. Another option would be using the same amount of for the craftsmen training purposes.

6.1. Practical Implications

The simulation system is an original tool which enables to carry out various economic researches in construction business, but also attract students for doing independent analysis. Construction-production functions are usable for optimization of the investment and construction strategies. The simulation model could be used as in construction firms as in university during the learning process of construction economics, construction planning and IT courses for comparing different planning strategies.

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