Logistic elements in the project involving the construction of about 700 meteorological and measurement stations

Introduction

As a result of the floor that affected southern river basins of the Oder and the Vistula in July 1997, as well as of floods in the previous years and local floods in 1998, as well as other phenomena being natural disasters (storms at the Baltic Sea, strong winds, sudden temperature changes), it has turned out that it is necessary to urgently upgrade the hydrological-meteorological system functioning in Poland, as managed by the Institute of Meteorology and Water Management, [10].

The disastrous effects of the flood could not be avoided at the contemporary condition of the anti-flood protection system and river valley management. Urgent needs included reconstruction of the damage caused and development of a more effective system for anti-flood protection system. Aid was offered by the World Bank, whose Mission arrived in September 1997 and, until November 1997, developed the main assumptions for granting a loan of USD 200 million to Poland. The Project of Mitigating the Effects of Flooding accounted for three components:

A – reconstruction of core urban and rural infrastructure,
B – anti-flooding protection and risk mitigation,
C – project administration and technical assistance (establishment of the Project Coordination Office).

The cost of component “B” – Anti-flooding protection and risk mitigation totalled USD 80 million. Within this component, four elements were accounted for:

B1 - planning the anti-flood protection in the catchment area,
B2 - monitoring, forecasting and warning,
B3 - investments in anti-flood infrastructure (the financial component funded by the European Investment Bank),
B4 - prevention and mitigation of the flooding risk.

Element B2 “Monitoring, forecasting and warning” was developed jointly with the specialists from the Institute of Meteorology and Water Management. The objective of the element was to establish, on the territory of Poland, of a complex system streamlining and facilitating the monitoring, forecasting and warning against dangerous natural phenomena, and gathering and broadcasting information about the present and forecasted status of the atmosphere and hydrosphere, [4]. This meant the construction of over 1,000 automatic telemetric measurement stations and supplying power to each of them, as well as installation of measurement and communication devices.

Furthermore, the logistic solution was analysed as regards the construction of 687 telemetric stations. The study involved execution of particular works occurring in four groups by type of facilities erected, with dispersed locations on a very large area, almost on the entire area of Poland, thus constituting a significant logistic challenge.

Organisational structure of contracting works and project logistics

The General Contractor (GC) was selected by way of tender. It was the Canadian consortium Hydro Quebec International. The consortium included the Canadian Hydrographic Service – an equivalent of

---

1 Prof. Eng. AGH University of Science and Technology, Department of Geomechanics, Civil Engineering and Geotechnics., al. A. Mickiewicza 30, 30-059 Cracow, e-mail: awiecko@agh.edu.pl
2 MSc., PhD student, e-mail: dgorska@tlen.pl
3 Reviewed article.
Polish Institute of Meteorology and Water Management. Via a Polish representative – a company dealing with advanced telecommunications technologies – the execution of particular construction tasks was entrusted to Polish companies, [1, 2, 3]. Funds from the World Bank reached Polish companies according to the scheme presented in Fig. 1.

![Fig. 1. Diagram of cash flow provided by the World Bank](source)

*Source: own study*

In order to carry out such a large, complex construction project, on a vast area of Poland, it was necessary to create, as soon as possible, specialist work groups with the following thematic scopes of work:

- logistics of the investment,
- preparation of construction projects,
- works execution,
- administration of contracts and controlling,
- guarantee repairs.

The logistic team of the project was in charge of:
- organisation and management of the accommodation base,
- organisation of warehouses in the field and management of stock levels,
- ordering basic materials and equipment,
- transport organisation and management.

The construction preparation team carried out:
- visits to the site, specifying local conditions in each location and individual scopes of work, for the envisaged structures,
- bills of quantities for particular facilities,
- takeovers of the site for the construction project.

The tasks of the works execution team included:
- scheduling, organisation, distribution of construction tasks, and getting the workers acquainted with the scopes of works,
- management of work sections and coordination of execution works (coordination of particular works in the field),
- active control and at the end of works,
- quantity surveying,
- works acceptances by the General Contractor.
The administration and controlling team was in charge of:
- contract administration,
- consultations and arrangements of problem issues with the Investor and General Contractor,
- continuous control due to legal conditions,
- invoicing,
- information flow: Subcontractor – General Contractor – Investor.

Defect elimination team organised the works in the area of:
- defect elimination,
- guarantee repairs.

The organisation scheme showing relations between works execution units in the field and specialist work teams, as well as information flow in the project of construction of meteorological and measurement stations, have been presented in Fig. 2.

**Fig. 2.** The organisation scheme showing relations between works execution units

*Source: own study*

**Work execution method and built-in materials**

An important task for execution of the construction of spatially scattered facilities on the large territory of Poland was to assure the required standard, identical for all stations, while preserving the necessary quality, as well as the shortest possible execution time. For this purpose, in project solutions, the application of prefabricated elements was maximised. All core structural elements were repeatable. While build-
ing the facilities of repeatable elements and in the same manner, the teams easily and quickly become fluent, very efficiently building the next stations, even more difficult ones, [2].

Due to the envisaged profile and scope of measurements, the stations were not uniform, and their structures varied. There were four main station types, with differing structure and scope of necessary construction works. These included:

- **ATSH station** – automatic telemetric hydrological station, with the simplest structure, comprising of a mast with the height within the range of 4m up to 10m, depending on the location and land characteristics, with the piping necessary for cable laying, with the length of from 1m to 300m,
- **ATSG station** – automatic telemetric ground station, comprising of a mast with the similar height between 4m and 6m, depending on the location and land characteristics, with the piping necessary for cable laying, with the length of from 5m to 600m, with the area of 4m x 4m, fenced with a systemic fence,
- **ATSO station** – automatic telemetric rain station, comprising of a mast, as above, between 4m and 6m, and rain meters, with the piping of from 5m to 70m, with the area of 4m x 4m, fenced with a systemic fence,
- **ATSM station** – automatic telemetric meteorological station, comprising of a mast of 10m, and rain meters, and with a meteorological box and the piping of from 5m to 50m, with the area of 10m x 10m, fenced with a systemic fence, [8].

Each of the above station types determined the types and volumes of built-in materials, according to Table 1.

Table 1. Specification of materials for particular types of stations constructed

<table>
<thead>
<tr>
<th>Ordered special materials</th>
<th>Mast, m</th>
<th>Station type</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATSH</td>
<td>4 + 10</td>
<td>4 + 6</td>
</tr>
<tr>
<td>ATSG</td>
<td>4 + 6</td>
<td>4 + 6</td>
</tr>
<tr>
<td>ATSO</td>
<td>4 + 6</td>
<td>10</td>
</tr>
<tr>
<td>ATSM</td>
<td>4 + 10</td>
<td>4 + 6</td>
</tr>
<tr>
<td>Foundation</td>
<td>prefabricated</td>
<td>prefabricated</td>
</tr>
<tr>
<td>Piping (kit), m</td>
<td>1 + 300</td>
<td>5 + 600</td>
</tr>
<tr>
<td>Grounding, kit</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Inspection box, kit</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Systemic land fencing, m * m</td>
<td>no</td>
<td>4 * 4</td>
</tr>
<tr>
<td>Rain meter base (foundations, poles), kit</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Stevenson Screen (foundations, support structure, meteorological box), kit</td>
<td>no</td>
<td>yes</td>
</tr>
</tbody>
</table>

*Source: own study*

According to the schedule for execution of particular stations, on the basis of visits to the sites, the construction works manager on behalf of the Subcontractor, and the representative of the General Contractor and the Investor determined the scopes of works individually for each station. On the basis of bills of quantities provided by the managers, the coordinating team in charge of the project logistics, considering the production capacity of the supplier and possibilities of building in the material by the teams, ordered the necessary quantities of specialist materials every week, according to the assortments available from the main supplier-manufacturer, with the instruction of full-vehicle deliveries to particular field warehouses in four regions.

Due to scattering of the stations and lack of direct supervision at the completed stations, usually after executing several facilities, construction works managers informed the coordinator of specialist teams about readiness of specific stations for acceptance by the General Contractor. After the formal acceptance, the liability for the facility (including station elements) was transferred onto the General Contractor. In such a case, in the event of a theft or intended mechanical damage, the subcontractor was not liable for the condition of the station handed over.
Work teams and equipment

The construction works were executed by teams of four workers. Supervision of the work of from two to five teams was carried out by the manager. In turn, the work of the managers in the area of organisation and complex coordination of works execution was supervised by the coordinator with five specialist task teams (cf. Fig. 2).

Each team was equipped with a lorry with capacity of 3.5 t, a mobile phone, working clothes, and the necessary equipment, including a platform for transporting heavier elements (with capacity of about 1 tonne), a power generator, wheelbarrow and spades, drills, and a surface vibration screed. The managers could use company cars, GPS devices, laptops, cameras, and mobile phones.

The works, by assumption, were to be carried out manually. Sometimes, however, due to difficult access to the land and difficult soil conditions, as well as significantly increased scope of works, it was necessary to use excavators and mobile cranes, which much shortened the execution time and the cost of works execution. In special cases, the works were carried out under the supervision of specialists, including an archaeologist.

Execution of works

According to the schedule for execution of particular stations, on the basis of visits to the sites, the construction works manager on behalf of the Subcontractor, and the representative of the General Contractor and the Investor determined the scopes of works individually for each station. On the basis of bills of quantities provided by the managers, the coordinating team in charge of the project logistics, considering the production capacity of the supplier and possibilities of building in the material by the teams, ordered the necessary quantities of specialist materials every week, according to the assortments available from the main supplier-manufacturer, with the instruction of full-vehicle deliveries to particular field warehouses in four regions.

The insufficient production capacity of prefabricated elements to be built-in required systematic coordination of the progress of works at the sites and the work of particular teams as compared to the possibility of supplying the necessary elements.

In a situation of the occurring delays in production, particularly regarding the masts, the central warehouse in Krakow had the intervention function regarding procurement. While having a minimum reserve, it provided single item deliveries of missing materials to the most delayed sites. In emergency situations, it organised dispatch of a full load according to the route planned, covering even several hundred kilometres, leaving the necessary material items at particular sites,[7].

Standard and generally available materials did not pose problems, they were ordered in wholesale volumes, usually from local suppliers, and possible shortages were supplemented on continuous basis in retail stores.

Due to scattering of the stations and lack of direct supervision at the completed stations, usually after executing several facilities, construction works managers informed the coordinator of specialist teams about readiness of specific stations for acceptance by the General Contractor. After the formal acceptance, the liability for the facility (including station elements) was transferred onto the General Contractor. In such a case, in the event of a theft or intended mechanical damage, the subcontractor was not liable for the condition of the station handed over.

Results of the solutions applied

The contract on execution of “Construction works on meteorological and hydrological stations” in the regions: Krakow, Wroclaw, Gdynia and Poznan envisaged completion of the construction works in a four-months’ cycle. Due to delay in the production of prefabricated elements of the stations, as well as organisational and legal problems on the Investor’s part, [6], works completion took place two months later. In turn, integration of all the elements of the project and its complete closure was executed in a pe-
period slightly exceeding two years. Therefore, execution of construction works lasted shorter than ¼ of project cycle.

Construction of 687 stations was carried out on average by 52 workers working in 13 teams of four persons, 10 work managers, a coordination team of ten persons, namely, in total, approximately 70 people employed on construction works. During the greatest peak of the works, falling in October 2004, the employment significantly increased to 21 teams of four, comprising 84 workers (increase by 62% as compared to average employment), supervised by 16 managers (increase by approximately 60% as compared to the average number during the construction).

Average construction time of a single station, regardless of the type, totalled 2.8 days.

Average construction time of an ATSH station amounted to 1.45 day, while the longest execution of such a station totalled as many as 23 days. The elongation of the time was caused by the delay in mast delivery.

Average construction time of an ATSG station was longer than for ATSH, and amounted to 2.14 days. The longest ATSG construction time totalled 9 days. The longer ATSG execution time, similarly as in the case of the ATSH station, was caused by the delay in mast delivery.

The construction time of an ATSO station on average amounted to 2.33 days, while the longest execution period totalled 31 days. The significant elongation of the construction time was caused by the delay in mast delivery and the need to improve works accuracy (during the acceptance, objections were raised as to the quality of works executed).

In turn, average construction time of an ATSM station amounted to 8.09 days, while the longest execution period totalled as many as 61 days, principally due to the delay in mast delivery.

While observing average construction times of particular station types, Fig. 3, one can clearly see proportionate elongation of their cycles with the increased volume of works and station complexity (cf: Table 1, ordered specialist materials).

Fig. 3. Construction cycles of particular station types
Source: own study

**Conclusion**

The untypical construction task involving almost 700 telemetric stations with differing structures, according to four main groups by type, with scattered locations on a very large territory, almost across Poland, planned in a four-months’ cycle (increased to six months during actual execution), was a significant challenge in the logistic and construction aspects.

Correct planning and effective management of the construction allowed for executing all the construction works in a short, six-months’ cycle, constituting less than ¼ project cycle.
Important logistic and organisational elements that materially affected the success of the project included:
- right distribution of scopes of works and transparent organisation of interdependencies between particular work execution teams,
- operative work on the part of the Coordinator and Specialist Teams, particularly Project Logistics and Works Execution, which, in a situation of insufficient efficiency of deliveries (production) of prefabricated elements, prepared weekly orders and systematically adjusted the profiles and scopes of works at the sites, in line with materials available,
- flexibility as regards the occurring limitations, manifested with the increase in employment, number of teams and work managers, particularly in the final period of station construction, and in cases of difficult land conditions supporting the teams with excavators and cranes, continuously adjusting to the potential deliveries of deficient prefabricated elements, which allowed for keeping the planned deadline for works execution,
- the concept of maximum prefabrication of built-in materials, and transfer of some works to a permanent plant (functioning in favourable factory conditions, with lower impact of staff imperfection and weather conditions) allowed for easy station construction of repeatable elements and quick learning on the part of workers at the sites, achieving short station construction cycles while preserving the required standard and work quality.

A severe disadvantage of the project, quite frequent in the Polish construction industry, was the increase in deliveries and supplementation of the systematically deficient types of prefabricated elements only in the final period of order execution (in the last month). The lack of necessary elements in the prior period caused long delays in work completion. In several cases, delays were even several dozen times longer than the average station construction cycle. Moreover, intensification of deliveries in the last station construction period caused a need for significant increase in the construction potential, by over 60%, with unfavourable urgent training of new workers in the works specificity. Also, very unfavourable peak in numerous work acceptance procedures took place at the very last moment. In order to prevent such drawbacks, contractual arrangements are necessary to guarantee systematic deliveries of full assortment of the materials needed, with predefined dates of clearing complete deliveries, in many intermediate stages.

Abstract

The establishment of the complex system to streamline and improve monitoring, forecasting and warning against dangerous natural phenomena, with the aid offered by the World Bank, required the construction of over 1000 automatic telemetric measurement stations, scattered across Poland, in project execution cycle of slightly over two years.

Organisational structures and project execution method have been analysed, determining the benefits of functioning of the Coordinator and five specialist teams, including Project Logistics Team, and other elements that guaranteed programme success, namely flexibility of the potential at the sites, adjusted to availability of materials, and maximum prefabrication of the facilities, which allowed for construction of the analysed about 700 stations, in a cycle of six months, which constituted less than ¼ project cycle.

In the execution works, delivery peaks could not be avoided, which resulted in significant increase in the number of workers and intensity of acceptance procedures in the last month of construction. Therefore, conclusions point to necessary contractual arrangements to guarantee systematic deliveries with full assortment of the materials, and multi-phase, complete settlements on predefined dates.

Elementy logistyki w projekcie budowy około 700 stacji meteorologiczno-pomiarowych

Streszczenie

Utworzenie kompleksowego systemu usprawniającego i ułatwiającego monitorowanie, prognozowanie i ostrzeganie przed groźnymi zjawiskami naturalnymi, z pomocą zaoferowaną przez Bank Światowy,
wymagało wybudowania ponad 1000 automatycznych telemetrycznych stacji pomiarowych, rozproszonych na obszarze Polski, w cyklu realizacji przedsięwzięcia nieco ponad 2 lata.

Przeanalizowano struktury organizacyjne i sposób realizacji projektu oraz określono korzyści funkcjonowania Koordynatora i 5-çiuj specialistycznych zespołów zadaniowych, w tym Zespole Logistyki Przedsięwzięcia oraz innych elementów, które zagwarantowały powodzenie programu, tj. elastyczność zastosowanego potencjału wykonawczego budów, odpowiedniego do dostępności materiałów i maksymalne sprefabrykowanie obiektów, w rezultacie umożliwiające wybudowanie badanych około 700 posterunków, w 6 miesięcznym cyklu, stanowiącym mniej niż ¼ okresu realizacji projektu.

W wykonawstwie nie uchroniono się jednak od spiętrzenia dostaw, w konsekwencji poważnego zwiększenia liczby wykonawców i intensywności odbiorów stacji, w ostatnim miesiącu realizacji budów. Stąd wskazano niezbędną, między innymi ustaleń umownych gwarantujących systematyczność dostaw, z pełnym asortymentem materiałów i wieloetapowymi, kompletnymi rozliczeniami, w narzucanych terminach.

**BIBLIOGRAPHY**


[6]. *Materiały z seminarium dla posłów Sejmu IV kadencji* zorganizowanego 8 kwietnia 2003r. przez sejmową Komisję Ochrony Środowiska, Zasobów Naturalnych i Leśnictwa oraz Biuro Studiów i Ekspertyz; Biuletyn Studiów i Ekspertyz Kancelarii Sejmu – Konferencje i Seminaria 5(49)03 „Ochrona Przeciwpowodziowa w Polsce”


[8]. Umowa na realizację „Robót budowlanych stacji meteorologicznych i hydrologicznych” w rejonach RBO Gdynia, RBO Kraków, RBO Poznań, RBO Wrocław, Kraków 2004.
