Training BIM Methodology in Civil Engineering: Short Professional Course

Alcínia Zita Sampaio, Augusto M. Gomes

***Abstract*—**The implementation of Building Information modelling (BIM) methodology in the construction industry has been covering a wide applicability with recognized benefits in designing, constructing and operating buildings. A recent short course organized in the University of Lisbon, actualized with the most relevant achievement based in master researches, was offered to professional of the industry, namely, architects and civil engineers coming from diverse engineering areas, environment, construction, maintenance, consult and patrimonial enterprises and also from public organizations like city councils. The proposed action covers the areas of construction (conflict analysis, planning and materials take-off), structures (interoperability, analyses and transfer of information between software) and the most recent Heritage Building Information Modelling (HBIM) perspective. The course aims to contribute to the dissemination of the potential of BIM in the areas of designing, construction and refurbishing of historical buildings. The participants followed the course with great interest and satisfaction, formulating several questions directed to the particular activity of each of the attendees.

***Keywords*—**BIM, training course, up-to-date information, skill professional skills.

I. Introduction

The Building Information Modelling (BIM) methodology is currently the main digital platform applied in the construction activity. A BIM project is developed over a technological platform, in which all experts create, manipulate and add the information that is required and generated in the context of the work of each professional involved [1]. In this process, the methodology supports the development of different components of the project, allows adequate interoperability between specific systems related to various types of analysis or simulation, facilitates the tasks of budgeting, construction, maintenance and management, also controls the eventual demolition [2].

The BIM concept began to be implemented in the construction industry at the beginning of this century as an immersive innovation in the sector. Its benefits were quickly recognised, reflected in the quality of the projects developed, based on effective process integration and clear collaboration between partners related to the different specialties intrinsic to construction [3]. BIM computational tools are a strong support for the development of the different disciplines of the project, enabling their parametric modelling and easy access to all the information concentrated in the BIM model created in the progress of the project.

In all areas of construction, the construction owner, designers, builders and managers, has verified the benefits of adopting BIM methodology. This fact has led to its growing acceptance, at a global level and in an exponential way, leading government entities to establish rules of action and mandatory implementation dates in public construction [4]. In addition, the school has the mission, essential in society, to train future engineers with the fundamental teachings related to different themes in the field of construction, and should also be attentive to the technological innovations applicable to the sector. Naturally, construction-related companies follow this perspective, encouraging professionals to seek training actions that can add to professionals the knowledge, in the BIM context, required in a globalized industrial world, increasingly competitive.

A short course, presented in March of 2022, included the methodological concepts and a wide range of the applicability sectors inherent to the development of projects in BIM. This text reflects the contents of the course and the main objectives. The organizational structure of the course introduces the underlying fundaments of the methodology, such as parametric modelling and interoperability, and presents the scope of the applicability of BIM.

II. BIM Education

The attention of Civil Engineering education is oriented to BIM, and it is up to the school, as the main trainer of the future engineer, to introduce this theme, as a concept that should be transmitted, contributing to support all new subjects, included in the curriculum, on a BIM-based digital support. The requirement of BIM skills in the sector, has imposed an educational maturity of alert in relation to the need in society, which has led to a progressive adaptation of the curricula taught [5].

The school have been contributing positively to the updating of knowledge of professionals in the sector, through the organization of BIM training courses, in accordance with the interest and expectation expressed by the offices and public entities. Industry and the school are partners in finding the best strategy for establishing effective ways of teaching useful to the community. In Europe, BIM training has been essentially

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introduced into postgraduate studies as curricular modules, disciplines or specialization courses. In reference universities, in Spain, Switzerland, Portugal and Italy, the curricular research points to a relatively rapid assimilation in engineering training.

- The *Escuela Técnica Superior de Ingenieros de Caminos, Canales y Puertos* of the Polytechnic University of Madrid offers two curricular actions [6]: a discipline of specialization, within the framework of the Master's degree in construction and management of facilities, with the aim of training professionals in the application of the BIM methodology, covering the entire life cycle of a building (project, execution and operation of the building), and the use of software required in modelling and information management; an advanced discipline of BIM methodology, in the master course of project management, with a more specific and detailed programmatic content (concept and applicability, BIM model management, collision detection, collaborative workflow, conservation and exploitation of infrastructures);
- At the *École Polytechnique Fédérale de Lausanne*, the study plan identifies the introduction of BIM at master's level through a discipline of introduction and application of BIM, covering the teaching of concepts (interoperability, IFC standard and LOD levels), the generation of parametric models and conflict detection, the transfer of information between systems, the estimation of costs (5D) and, construction monitoring (4D);
- At the *Instituto Superior Técnico* of the University of Lisbon, at the level of the 1st cycle of teaching, the curriculum of the discipline of Technical Design includes an introduction to BIM, where the procedure on parametric modelling is transmitted, using BIM-based tools;
- The curriculum, of the *Collegio di Ingegneria Civile*, at Polytechnic University of Turin, offers in the 2nd cycle of education, a master's course in BIM applied to infrastructure, which includes aspects related to modelling and computer content, interoperability and formats, collision detection, structural dimensioning and real case analysis (bridges, tunnels, stations, schools and hospitals).

In addition, the construction industry has demanded from schools an offer aimed at the specificity of the profession, focusing on different perspectives. Engineers and architects recognize that in a globalized world, in the pursuit of their activity, the use of BIM platforms, leads to the achievement of better products and the establishment of more competitive projects. The constant demonstration of the benefit inherent to the use of the BIM methodology, which has been registered in the various sectors, motivates designers and managers to acquire knowledge related to the concept and scope of its applicability. Professionals from all sectors are interested in knowing the BIM concept and the scope of its applicability and technical schools organise BIM training activities to help to add knowledge and competitiveness to industry professionals.

III. Professional course

The professional course, *BIM methodology: construction, structures and HBIM*, included within the activities of the Department of the Civil Engineering, of the University of Lisbon, was the most recent event offered to professionals of the construction industry. The range of professional englobes architects and civil engineers coming from consult enterprises and public organizations. The objective in attending the course was to improve there skills in order to increase competences in each particular domain of activity in construction. The program in presented in Table 1.

TABLE I
Professional course “BIM methodology: construction, structures and HBIM”.

Topic	Contents
Building Information Modelling (**BIM**)	Concept, applicability and implementation; Parametric modelling, interoperability, and centralization; BIM tool practice in generating model structures.
BIM in the **construction**	Conflict analysis; Adding parameters to objects; Construction planning; Quantification of materials.
BIM in **structural** design	Interoperability; Transfer and consistency check; Graphic documentation and information centralization.
Heritage Building Information Modelling (**HBIM**)	Concept and collection of information; Digital capture of images (photogrammetry, scanner and drones); Generation of specific families of parametric objects; Documentation file (as-built); Practical case: reconversion of a heritage building.

A. Introduction to BIM

The introduction of the main fundaments of BIM started with the principal concept, the range of applicability and the state-of-the-art of its implementation. The central BIM notion is the generation of a centralized digital model of all construction-related information. BIM is frequently defined as a digital representation of the building or infrastructure, strongly supported by parametric modelling and standard formats of data. Collaborative projects are developed over the model, requiring the use of advanced technologies and a high level of interoperability.

A practical lesson concerning the use of BIM-based tool, introduces the concept of parametric modelling, essential, to the understanding of the development of multitasking. In the modelling process, the first step is to define the base settings (work units, elevation levels, and alignments), followed by the selection and adaptation of parametric objects, associated to physical properties [7]. As an example of how to handling with a BIM-based tools, a structural BIM model was created (Fig.

1). After, there were obtained several tables of take-off of materials and elements from the generated BIM model [8] (Fig. 2).

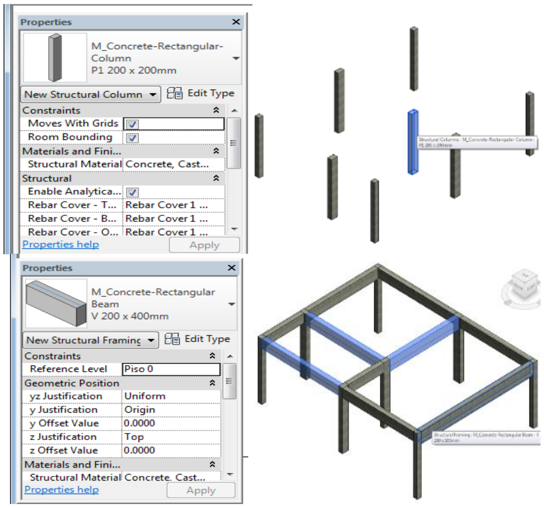
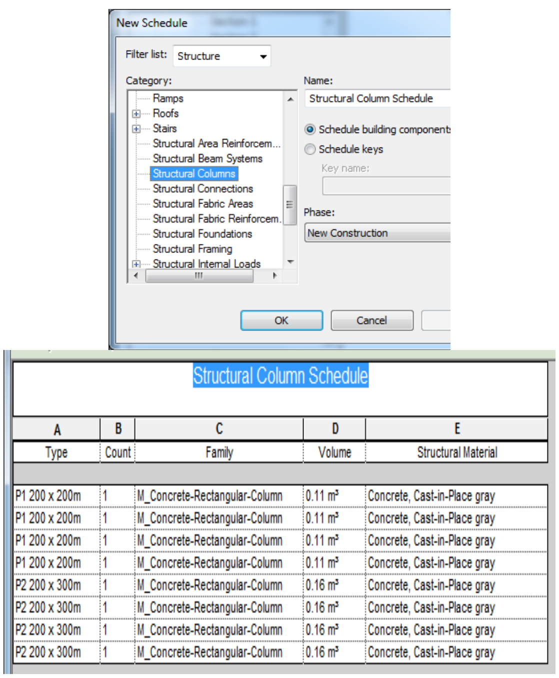


Fig. 1. Modeling columns and beams.



Structural Column Schedule				
A	B	C	D	E
Type	Count	Family	Volume	Structural Material
P1 200 x 200m	1	M_Concrete-Rectangular-Column	0.11 m^3	Concrete, Cast-in-Place gray
P1 200 x 200m	1	M_Concrete-Rectangular-Column	0.11 m^3	Concrete, Cast-in-Place gray
P1 200 x 200m	1	M_Concrete-Rectangular-Column	0.11 m^3	Concrete, Cast-in-Place gray
P1 200 x 200m	1	M_Concrete-Rectangular-Column	0.11 m^3	Concrete, Cast-in-Place gray
P2 200 x 300m	1	M_Concrete-Rectangular-Column	0.16 m^3	Concrete, Cast-in-Place gray
P2 200 x 300m	1	M_Concrete-Rectangular-Column	0.16 m^3	Concrete, Cast-in-Place gray
P2 200 x 300m	1	M_Concrete-Rectangular-Column	0.16 m^3	Concrete, Cast-in-Place gray
P2 200 x 300m	1	M_Concrete-Rectangular-Column	0.16 m^3	Concrete, Cast-in-Place gray

Fig. 2. Interface with selection and table of columns extracted from the model.

B. BIM in construction

An analysis of the detection of conflicts between projects was also exposed to the audience. The BIM modelling tools allow the overlap of the three disciplines (architecture, structures and mechanic) and support the definition of each component by direct analysis of conflicts, identified by the system with the issuance of inconsistency messages. There are several software with conflict analysis-oriented capabilities, namely, Tekla BIMsight, Navisworks, and Solibri Model Checker tools. After running any of these systems, the modeller adjusts each conflict situation over the BIM model. In the study case show in the course, the models of MEP and structures were overlaid and an analysis of inconsistency was applied. Using Navisworks and Tekla BIMsight a set of conflicts were listed and visualized (Figure 3). The conflicts detected were after adjusted accordingly in order to obtain correct situations (Figure 4).

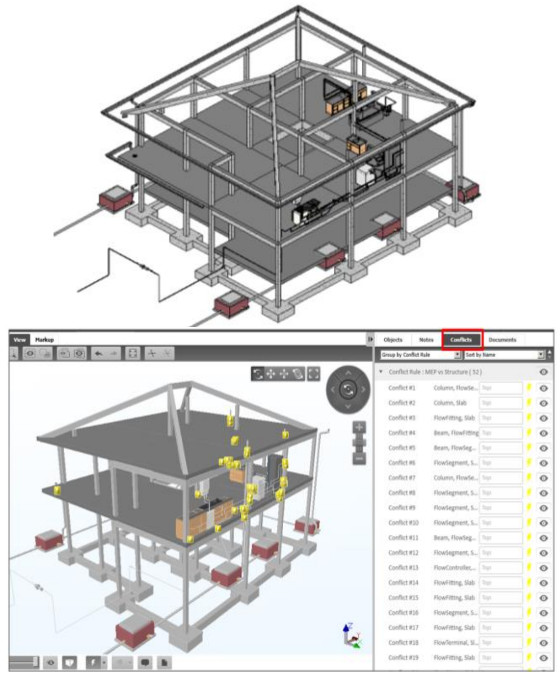


Fig. 3. Analyses of conflicts between models.

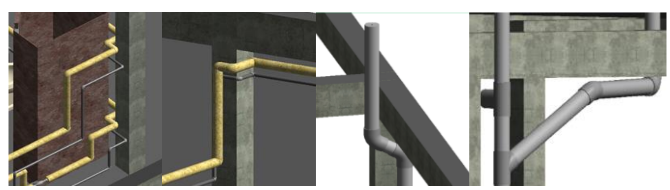


Fig. 4. Changes were performed in a BIM modeller software.

The course illustrate how to generate a 4D BIM model, relating to the construction process of a buildings [9]. First, the complete 3D BIM model of the structural project must be defined and after the constructive sequence planning (phases and periods of implementation or placement) and allocated human resources must be established in the form of a Gant map (Fig. 5).

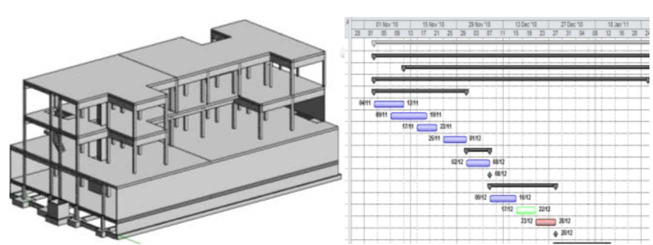


Fig. 5. 3D BIM model of a structural project and the Gant map.

The 4D model is then created in the Navisworks software. The BIM model representing the structural project is exported from the modelling system to a BIM viewer, performed in the native format. Also, the construction planning (Gantt map) file is transferred from the Ms Project system to the Navisworks. Next, it is necessary to associate the elements of the imported model, forming groups (sets), according to the activities of the schedule (Fig. 6). The 4D model allows to visually simulate the planned construction (Fig. 7).

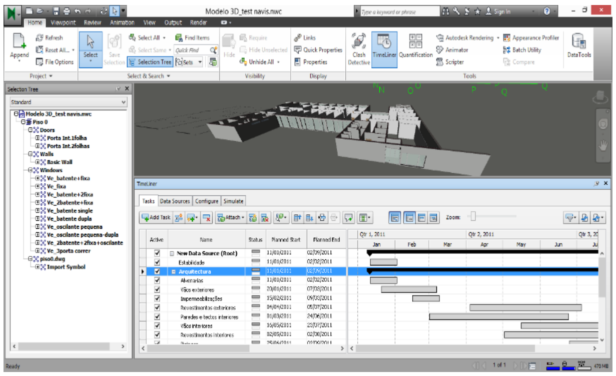


Fig. 6. BIM 4D model generation.

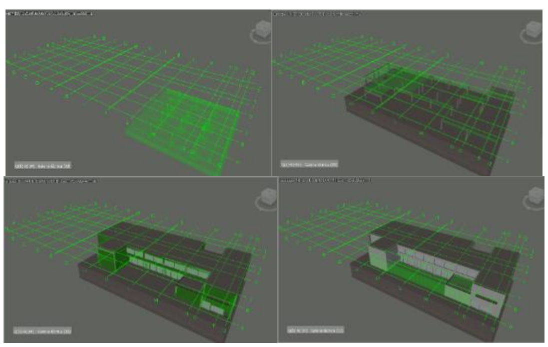


Fig. 7. Simulation of the construction process.

C. BIM in structural design

Throughout the development of a project and later construction and use, several processes transferring data between software, are normally performed, and for that, a high level of interoperability is required. In a structural design, the transposition of models between BIM modelling and structural analysis tools is essential. Concerning the structural design, the interoperability capacity, the transfer and verification of consistencies and the centralization of information and graphic documentation were performed [10].

In the course, the process of transposition of structural models between modelling and calculation systems (two-way flow) was analysed in several situations involving ArchiCAD, Revit and AECOsim modelling tools and SAP, Robot and ETABS structural dimensioning tools [11]. The transposition of models between systems is supported: in the native format, when the software belong to the same manufacturer; by recourse to the universal data transfer standard, the Industry Foundation Classes (IFC) format. The interoperability capability analysis, verified in each model transposition process, is evaluated over several case studies of distinct volume and use (Fig. 8).

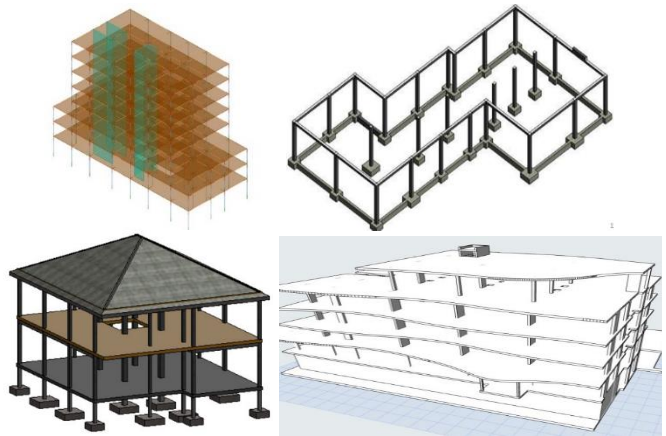


Fig. 8. Structural BIM models of distinct buildings.

First, the BIM models were transferred from the modeller system to the analyses software and the geometric consistency was evaluated. Several inconsistencies were observed: stair elements were not recognized (remodelled as sloped slabs in the analyses system); the foundations were not transposed (considered as supports). However, the structural elements (columns, beams and slabs), grids and material, concrete C30/37 and A500 NR SD steel were correctly transposed, but the analytical axis of some linear finite elements and rigid connections were adapted (Fig. 9).

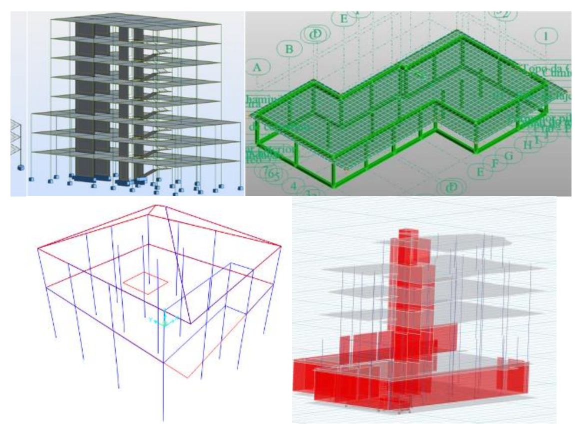


Fig. 9. Structural BIM models transferred to analyses software.

The level of interoperability between BIM-based modelling and calculation systems was assessed and it was found that: there are advantages of using Revit/Robot integrated platforms; the data flow modelling/calculation can be done with confidence, while the reverse flow is inefficient; the advantages are essentially related to the easy initial modelling, with some ability to transfer information post-calculation; it is appropriate to perform the detailing of reinforcements in the calculation system, as it allows a high capacity for the production of 3D designs and, subsequently, the inaccuracies are easily adjusted.

D.HBIM concept

A recent implementation perspective the Historic or Heritage Building Information Modelling (HBIM) is directed towards properties of historical value or heritage relevance. Recent research related to HBIM addresses [12]: the standardization of architectural configurations and creation parametric objects representative of applicable and reusable forms in the old construction; the analysis of constructive techniques used in order to identify the materials used and the solutions applied; the archive of registration documents, studies carried out or previous interventions, and their availability for consultation by experts involved in the project.

It is required to understand geometric rules, in parametric terms, from the books of architectural patterns to the HBIM modeling process. Sets of specific parametric object must be generated to allow the generation of old buildings with accuracy (Fig. 10).

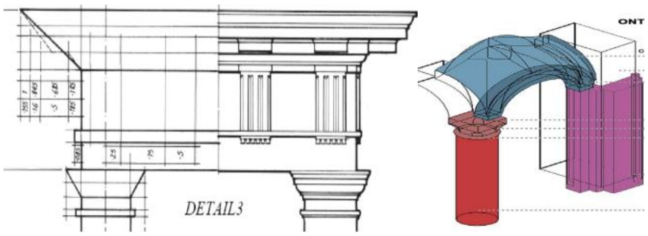


Fig. 10. Architectural configurations and creation parametric objects.

The documents of the Municipal Archives provides data concerning the characterization of the construction (historical epoch and traditional construction systems), the registration of refurbishing interventions and local inspection reports. In addition, the documentary collection, along with municipal archives, composed of drawings of plants, elevations and cut, referring to different dates and with yellows and reds, bring a complete description of the old building (Fig. 11).

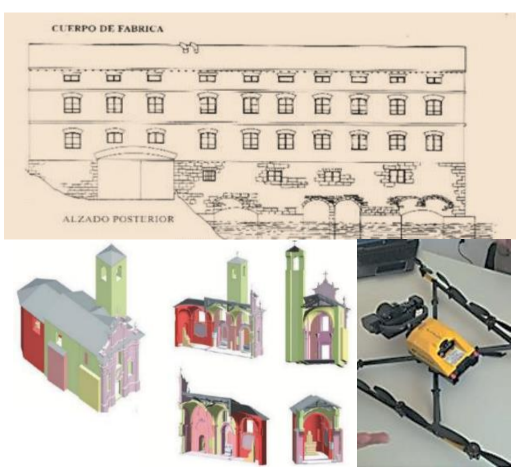


Fig. 11. Antique drawing of an old building, stratigraphic representation and a drone.

The stratigraphic analysis covers the study of the constructive steps, which are represented through different colours, leading to a clear visual perception. In an HBIM process, it is also frequently necessary to establish a station of laser devices, properly positioned, so that, later, the points obtained can be unified, in a single cloud of space points (Fig. 11).

A practical case of reconversion of a building of heritage value was presented [13]. A proposal for the adaptation of an old building, located in Lisbon, requiring the reorganization of internal compartmentalization, but preserving their architectural characteristics, illustrated an application of HBIM (Fig. 12).

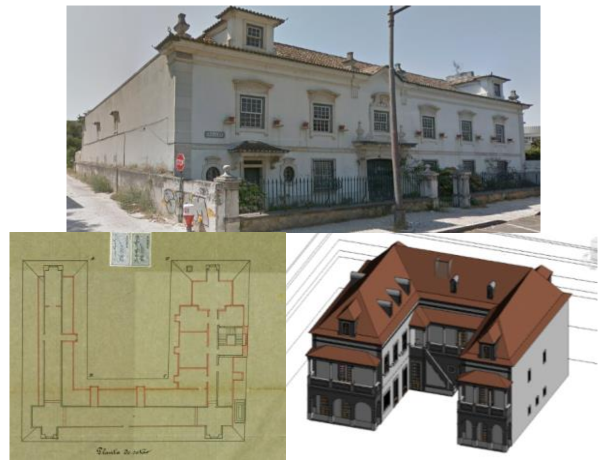


Fig. 12. Building of heritage value, old drawing and BIM model of the proposal.

Within HBIM, the creation of families of specific parametric objects was required for the rigorous representation of a building of patrimonial value. As a basis for modelling, it was requested to collect the existing documentation in the Municipal Archive of Lisbon, to obtain photographs from outside and inside of the building and the registration of detailed sketches. In addition, to allow a correct geometry represented in the form of parametric objects, it was necessary to add the material type and adjust the physical and mechanical properties, in order to respect the ancestral techniques of construction. The work contributes to empowering the HBIM library of parametric objects of building components.

IV. CONCLUSIONS

A one-day course, *BIM methodology: construction, structures and HBIM*, was offered, at the University of Lisbon, to professionals of the construction industry. The contents of the training action was organized in order to cover a wide range of the applicability of BIM in the sector, and with the most recent achievements. The participants demonstrated a global interest in all topics presented, formulating questions oriented to their particular expertise. The global satisfaction of the attendance was good.

The main purpose of the course was to transmit the main concepts, the strategies of working in each type of BIM application and the reference to the main benefits and limitations. All parts of the course, including practice, construction, structures and HBIM, were essentially illustrated with study cases selected in accordance with the audience. Industry professionals feel the need to update themselves in the BIM context and the course contributes in a positive way to this learning. An in it the school and the industry collaborated in order to establish an interesting and useful program.

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