# What price the cathedrals?

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Many have written about the sums of money spent on building the cathedrals of the middle ages, but few have made the calculations.[1] We have not enough information to compare medieval costs with ours. Over the centuries wages have increased twice as fast as the price of foodstuffs, while metals have been relatively sluggish. How then can we calculate the cost of a complex work like a cathedral when no two items have increased at the same rate? The difficulties are so great that few have attempted a serious study, yet the rewards would seem to be considerable.

I decided to approach the problem by ignoring the change in values, techniques, productivity and efficiency since the Middle Ages, and to cost a medieval cathedral as if we were building it today. I did this with the tireless help of Ken Greene, a Trappist monk turned quantity surveyor. We measured all the building work done in the cathedral of Chartres between the fire of 1194 and thirty years later when the transepts were completed.[2] We used the same materials – stone, wood and lead – as the medieval builders but made use of modern cranes, scaffolding and mechanical tools. In this way we hoped to arrive at a figure that would be meaningful in the twentieth century, for we should be able to compare one building element such as stained glass or sculpture with another. Also, we could assess the amount spent by each building team.

Since I had already determined the location of all the construction joints within the structure I knew how much work, including sculpture, each contractor had carried out; and each team's work had been set out and was readily measurable on thirty five isometric drawings.[3] Further, two contemporary documents gave enough information to date every campaign to within a couple of years between the 1194 fire, which seems to have destroyed all but the western end of the old cathedral, and the completion of the new choir vaults in 1220.[4] By setting the amount spent by each team against the reasonably accurate dates for the work of that team, we should obtain a cash-flow chart for the expenditure over a thirty-year period. Moreover, the ebb and flow of funds would provide clues to the economic forces at those times in much the same way as do modern statistics.

Were scholars to apply such methods to other structures, we could in time compare like with like to see what sums of money were being spent across northern France at that time, the rhythm of funding in one place as compared to another, and the capitalisation per head as a function of estimated productivity.[5]

This method avoids the interminable entanglements that have bedevilled other attempts to cost the cathedrals. Retrospective costing seems to force the researcher to select rates in a necessarily arbitrary way, and other scholars readily take issue with the selection without being able to agree on a solution. We hoped to provide a tool independent of "guesstimates" which could be used for comparison of all works of the selected period.

We began this study in 1969 but left it unfinished until I returned to Sydney in 1970. The present figures in the first table are based on the costs ruling in September, 1972, in the State of New South Wales, Australia, when the exchange rate was about 2 Australian dollars to £1 sterling or 12 French francs.[6] The table lists the rates used. If applied to other churches they may have to be varied if the vaults are smaller, or the walls made of rubble rather than ashlar, or where the materials came from greater distances.

To convert this sum into modern figures, I applied the Australian Building

Economist Cost Index used in the industry to calculate cost rises during construction. It is a general index designed for standardized large-scale and repetitive structures like warehouses and shopping malls.

The index has risen from 138 in 1972 to 1,630 in 2018, a twelve-fold increase.

However, the real situation is more complex. In the past thirty years building costs have been considerably reduced with new materials, better fabrication methods and site management, and the use of mechanization to replace skilled labour with the relatively unskilled.

I discussed these issues with professionals engaged in quantity surveying and costing. They suggested we compensate for the use of masonry, technological improvements and the disappearance of hand-crafting by increasing the index by at least 70 percent. This computes to an effective eleven-fold increase since 1972.

We took bulk quantities for all obvious items, and applied bulk rates calculated in detail, [table, next page]. In this way the rate for, say, a wall would include cutting and quarrying, carting to the site, hoisting and laying, mortar and so on. We measured walls at their overall volume less openings, and either applied a rate around the perimeter of each opening for the cutting of jambs and formerets, or slightly increased the volume measured. Similarly, we dealt with roofing, pillars and vaulting. Some items, like individual sculptures or the formwork for each cell of a vault, were given unit rates that was multiplied by the number of units. To these base rates we added the following percentages to cover

| | |
|---|---|
| minor unmeasured items | 10 percent |
| design costs, site control, shed | 8 percent |
| contingency factors, mistakes | 5 percent |
| builders' profit | 8 percent |

This increased every rate by 30 percent. By this method we calculated that the total cost of a new cathedral for Chartres (in 1972), just like the old one, glazed and with all sculpture and the vaults plastered, would be $42,429,000.

Therefore, the cost of Chartres in 2018 would be about $830 million Australian. From here on all figures are in 2018 Australian dollars.

Considering there are no mechanical services, no lifts and no electrical, no security, communication gear or hydraulics, this seems a fair price for a shell of this size and complexity.

The cost of carriage was one of the largest individual items in medieval accounts. The limestone for Chartres came from Berchère, only 12 kilometres away, not too far by medieval standards. We calculated that it would have taken a team of five oxen all day to deliver a ton and a half of stone from the quarry to the site. If the stones were already squared to eliminate unnecessary weight, with only one team it would have taken almost 1000 years to cart it all to the site. For our costing we used modern diesel-driven trucks.

As the building rose, it would have taken longer to lift each block of stone, scaffolding would have got more costly, and the men would have had further to climb each day. To compensate for this extra time and cost we increased the rates with the height by many small increments. Compared to walling at ground level, that at triforium level was increased 22 percent, and at the roof gables by 70 percent.

Medieval cranes of the type illustrated in many manuscripts, and still found at Mont Saint-Michel, were slow in operation. There was a large drum and to this was attached a smaller drum round which was wound the cable. One or more men drove the larger drum by walking inside it, a slow and sure method of raising blocks of stone. Though there is no evidence for lewis bolts in any part of Chartres, there is evidence in most demolished buildings of that period.[7] To avoid delay at least four large cranes working

Rates used for costing

| Type of Work | Details | Rates in $A | Further Details | | |
|---|---|---|---|---|---|
| Demolition | Walls | 11 per centimetre | | | |
| | Vaulting | 55 per centimetre | | | |
| Excavation | depth of 4.5m | 12 per centimetre | no shoring, dry conditions | | |
| Walling | foundations | 220 p.c.m | rough face work at same rate | | |
| | face walling | 350 p.c.m | at ground level, increasing with height | | |
| | | 450 p.c.m | at triforium floor | | |
| | | 500 p.c.m | at clerestory walkway | | |
| | | 550 p.c.m | at clerestory roses | | |
| | | 600 p.c.m | at the roof | | |
| | triforium columns | 1100 each | + $A200 for formwork of arches | | |
| | triforium arcade | 110 each | where small and low down, rising to arc | | |
| | | 340 each | | | |
| | voussoirs | 900 each | main arcade + 8,000 for wall over | | |
| Vaulting | formwork | 200 each | Chapels 500 | Aisles 500 | Towers |
| | stone ribs | 400 each | 1350 | 1500 | 4500 |
| | cell formwork | 1400 per bay | 1110 | 1450 | 11000 |
| | cell stone | 5500 per bay | 4800 | 4800 | 17500 |
| | mass fill | 38 p.c.m. | 3300 | 3300 | |
| | stripping | 1600 per bay | | | render 2 |
| | transverse arch | 13000 each | | | |
| Clerestory | roses | 13000 each | | | |
| | lancets | 6500 each | for all stonework | | |
| Flyers | formwork | 500 each | | | |
| | stone arches | 4500 each | | | |
| | spokes | 5500 per set | | | |
| Roofs | surface | 55 p.s.m. | measured on face | | |
| | structure | 30 p.s.m. | measured on face | | |
| | raise roof | 45 p.s.m. | measured on face | | |
| Sculpture | wall figures | 5500 each | carved and erected | | |
| | small panels | 450 | | | |
| | lintels | 4500 | small | | |
| | | 6500 | large | | |
| | tympani | 7500 | small | | |
| | | 11000 | large | | |
| | arch | $50 each | for average size over one figure | | |
| | | 550 each | small | | |
| | gable panels | 3000 | small | | |
| | | 5500 | large | | |

full time would have been needed to hoist all the material. Once hoisted, each stone still had to be moved along gangways and manhandled onto mortar beds. The weight of an average stone was about 250 lbs, and many weighed much more. Some of the roof paving in the triforium and some of the sills and bosses must weight almost two tons, and the difficulty can be imagined of moving such stones horizontally on timber staging poised high above the ground, and working them accurately into position without damaging their details. For our costing we have used two mobile long-armed cranes running on rail tracks along each side of the building.

The cost of scaffolding for the walls has been included in the bulk rates, but formwork for arches, ribs and vault cells has been set down separately. The carpenters probably worked in separate teams from the masons though under the general direction of the master mason. The evidence suggests that for heavy and complex timber-work the forms were often erected in a separate campaign from the stonework they were to support.

The entire cathedral was constructed in layers, each Master working in succession across the whole site. The western end was always some metres higher than the eastern, with a slight tilt to the north. This tilt first appears in the work round the crypt, and continued to the last work on the choir roof, so the western vaults were commenced first, and work proceeded in sequence towards the east. At transitional points it would not have been unreasonable for one or two bays to have been shaped by one team and the masonry laid by the next. The initial reason for the tilt was that the chalk foundations were also tilted, and consequently we allowed for deeper footings, with deeper trenching and shoring, at the eastern end.

The terminal walls of the transepts were begun later than the nave, though this order was not necessarily due to deeper footings. In other buildings the clergy often had to delay work while they negotiated for and bought adjoining land. Chartres Cathedral was in the centre of the medieval town and adjacent houses would have been the most sought after by merchants and noblemen, and more difficult to compensate for than land further away. We therefore assumed that the transept footings were delayed in time rather than dug deeper into the ground. All the excavations and foundation stonework have been spread over the four campaigns before team "Bronze-E" in 1198 built the crypt doorways in the transepts and began the vaults for crypt chapels.

We have assumed that the eastern end of the old church, with its heavy concrete vaulting, was not destroyed in the fire and allowed for repairing the roof and temporarily closing the open end near the present crossing.[8] There is evidence that this eastern end was not demolished until the last possible moment so that services could be held in the building during the construction of the new work. It is not easy to pull down an old building, particularly where the walls are pierced by three-storied arcades and where some of the vaults are of solid mortar.[9] By the end of the first campaign the new work at the west end was well above the ground, and demolition teams had now to be careful not to let any rubble fall onto the new work and damage it. This caution would have increased the cost, which we estimate at $4,555,000. We assumed that most of the old material was re-used in the new footings or within the thickness of the lower walls, and consequently we mad an adjustment to the cost of the work below ground.

After all the old church had been removed the most pressing ecclesiastical need would have been for an adequate space for services. Once the nave had reached the level of the aisle sills (about 4 metres above floor level), we presumed that a temporary roof would have been thrown over the nave so that the entire space below could be used while construction continued above. Between 1200 and 1203 $4,600,000 was spent on a temporary roof over

most of the new building, so that within eight years of the fire the cathedral was re-opened with more floor space than before. Between 1201 and 1213 this temporary roof was raised to the level of the clerestory sills. We costed for new timbers but a 70 percent re-use of the old lead that could have been collected and recast even if melted by the fire. However, as the scaffolding was supported on the top of this roof[10] rather than being taken all the way down to the ground, its timberwork had to be much stronger than usual and had to be costed accordingly.

After 1223 the work on the southern rose was nearing completion and the clerestory level of the northern transept towers was being set out, the campaigns became smaller and smaller until the last ones, on the gables and flanking turrets, could be costed in only four or five figures. We then decided to enter the work of the last few years at an unsubdivided figure of $8,316,000, the work of sixteen or seventeen campaigns. It was a sign of the decline in funds as the work was being finished that each master in the 1230s and 40s was completing less than a quarter as much as his predecessors.

The dating of the stained glass is still an unsolved question and we decided not to include it in the cash-flow chart. The glass would not have been ordered until the windows were cut, and probably not before they were erected. The few dates that the experts seem prepared to give to some of the glass panels fit in well enough with the dates for the architectural work.[11] The total cost of the glass came as a surprise: it was not a large item at all. Working on modern French prices we estimated that at the most it would have cost only $83,000,000 supplied, leaded and installed, or about 10 percent of the total cost of the fabric.[12] Suger's comment that the glass for the church of Saint-Denis came from the church collection boxes filled with the mites of the pilgrims shows what a small part of the total cost of a cathedral was borne by ordinary people. No doubt they gave as generously as they could to the fund-raising campaigns but the above comment suggests, as does our commonsense, that the bulk of the cost of these enormous buildings had to come from the wealthy. One of these, Louis the Pious, is shown under the feet of Christ on a carving in the south porch, set there a couple of years before the donor set out on the Fourth Crusade, during which he died.[13]

The costing of the sculpture was not easy to assess. We decided to make an exception and not cost at the price we should have to pay today for such masterpieces, the modern art market being so inflated. Instead we struck for each piece, irrespective of its artistic merit, a figure calculated on overall size and complexity. The work is on very fine-grained stone that came from the great quarries to the west of Paris and along the Oise. The blocking-in may have been done at the quarry, and finished on site, under cover.[14] Some had to be stored for a number of years before being put into position.

Erection would not have been easy as the work was fragile and the material ponderously heavy. Formwork would have impeded the work and so would have been kept to a minimum. More ingenious and more costly devices would have been needed to move the statues and place them.

There is no contemporary evidence that more was paid for sculpture than for any other skilled work, nor that this type of carving was a special activity paid for on a different scale from other work. So we decided to apportion generous time for the work on each piece, to add 30 percent for thinking and design time, and to cost the labour at a rate of 30 percent more than the rate that we should have paid a leading hand. After discussions with a number of artists and builders as to time and erection methods, we agreed to rate the great column statues at $140,000 each – carved and erected, and the archivolt figures at a maximum of $16,800 a panel. We entered the small lintels at $11,500 and the large central one at $166,000, while the tympani over were

costed at more than $180,000 and $280,000 each. The proportions between these figures could be adjusted or modified to taste, but they would probably not make any significant difference to the total, which we found as surprising as the total which we obtained for the glass. The full cost of the sculptural decoration in the porches – excluding capitals, cornices, projecting heads around the flyers and so on – came to only $26,000,000, less than a third of the cost of the stained glass!

This figure is low compared to the importance it plays in the impact of the building. Yet the more we thought the more we realised that the sculpture, great as it is, plays a relatively secondary part in the entire concept. Compared with Indian and Indonesian temples, compared with the incredible complexity of the sculptural programme in the temples of Angkor and Yucatan, or compared even with the sculpture on the Acropolis, the porch sculpture at Chartres makes a smaller impact, though Chartres has much more sculpture than any other contemporary European building. Admittedly it is concentrated where it can best be seen by those entering the church: it is not too high nor scattered uniformly over the surface so that the individual impact of each piece is blunted, but it is placed with great care in order to have the maximum effect on the worshipper. If the masters were in any way influenced by any sort of cost analysis, they must have been aware of the small sums allocated for sculpture compared with the vast amounts for architecture. There is almost no carved work on the interior, which was created as a spare yet intricate group of spaces. The sculpture, by being placed in the porches (see Plate) was like the embroidered hem of a dress. It highlit specific points and was a focal rather than an integral part of the whole concept, the reverse of Hindu architecture.

This is not to say that the sculptural programme was unimportant; on the contrary it was of the utmost value for it made visible the essence of the doctrinal truths that underlie the great edifice itself. The masters, by limiting the sculpture to a small area, concentrated a maximum effect on the viewer.

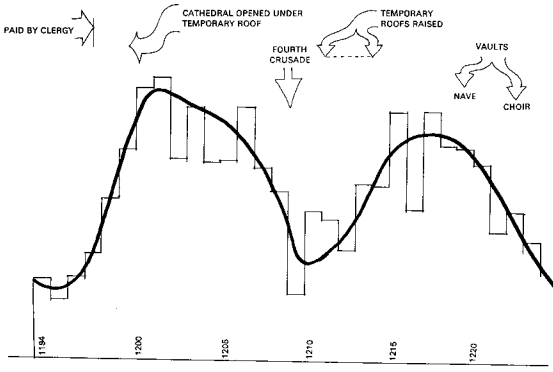
The sculpture formed only a small part of the total cost – three percent at Chartres and therefore less elsewhere – which suggests that we should recognise that for the churchmen who worked to raise the money, and for the people who made the sacrifices to pay, the most important part of the cathedral was the enclosed area. The search for simple, relatively unadorned architecture consisting of masses and spaces, of rhythmic bays and complex geometry was the most compelling goal of the period, for which men were prepared to lay out most prodigious sums, encumber their land with excessive mortgages, and donate their jewels and heirlooms. Architecture was the major cultural expression of the age, and immeasurably more important than the stained glass or the sculpture that went with it.

Comparisons are often unfair, but we can gain some idea of the place of the cathedral in the medieval community when we realise that Chartres cost the same as the Sydney Opera House shorn of its mechanical equipment. We do not know how many people lived in the region round Chartres in the early thirteenth century, but it has been estimated that there may have been close on two and a half million people in the area of northern France which produced the Gothic cathedrals.[15] On a quick estimate I have calculated that in a century and a half these people built fifty major religious buildings and four hundred significant churches, abbeys and retreats, quite apart from small unadorned parish churches and monasteries, military works, palaces and ordinary housing, a magnificent and almost incredible effort that has few parallels among non-industrialised countries in the history of the world. By comparison Sydney, with the same population, would have to build three Opera Houses in each municipality in the metropolis over almost the same

period of time as the white man has occupied the continent of Australia!

Only in the last few years (written in 1971) has Sydney begun to compete with medieval France in the scale of her buildings; but with office blocks, freeways, public works and other products of an advanced technological community there is little time and money left for non-utilitarian buildings. Medieval France dedicated herself to the construction of enormous spaces for religious purposes and for a short time seems to have worked with a single-minded and exclusive enthusiasm.

The cash-flow chart, [next page], shows how the funds fluctuated each year. I have given each building campaign one year for its work, and the amounts spent are represented by the vertical bars. The figure highlights a number of points that could only be determined from a relative study such as this, which produced a pattern of the greatest significance, [right]. Firstly, there were two periods of peak activity. The funds spent increased year by year until, in a climax of enthusiasm, larger and regular amounts were raised each year for some eleven years. Around 1209 the work dropped off sharply, and then slowly built up again to a new if less impressive plateau that culminated in the completion of the nave and choir vaults in about 1220. Once the vaults were complete the work slowed down to less than a tenth of its peak. At the end, not shown on the chart, were a further sixteen campaigns which finished the upper parts of the two transepts, all the gables and the beginnings of the north-west tower.




The factors that caused the funds to surge and wane must have been complex, depending on local politics, the state of the economy, good and bad markets, individual enthusiasm and many other influences that may for ever remain unknown to us. However, there are a number of points that seem too coincidental to be fortuitous. Firstly, note that the initial increase in the funds kept step with the growth of the building. As the massive structure rose out of the ground and the remnants of Fulbert's church were demolished the people could see the scale of the new work, and gave accordingly. The huge sums donated for campaigns F and G, sums which were never again equalled, coincided with the erection of the temporary roof over the nave and most of the choir. Up to that time the pilgrims had had to squeeze into the old crypt: perhaps the document that refers to the crowd in front of the altar of St. Lawrence in 1198 refers to this.[16]

Once the temporary roof was completed nearly the whole interior of the future cathedral could be visited, and it would not have been unreasonable for the clergy to have used this first view of the new work to stimulate further gifts. The second surge may confirm this idea, as it coincided with the raising of the temporary roof to clerestory level. Once the great height of the building could be seen and the triforium opened to view from the paving on the ground floor, the clergy could demonstrate the grandeur and importance of the work in a direct visual way. Similarly, later on when the people saw that the bulk of the work was completed and the main vaults in place, donation would begin to dry up and the work slow down. After all, this was not the only cathedral being built in France, and there must have been many collectors moving from town to town raising funds for the great works at Reims, the new cathedrals at Amiens and Paris, and a host of others. The last works at Chartres was probably completed from local funds rather than from the coffers of the whole country.

The dip in the middle of the cash-flow chart coincides with the military campaign against the Albigensians in 1210 in which Bishop Mouzon of Chartres lead a contingent. The smallest building programme of all, that of "Cobalt-O", was in 1209, when all available funds may have been diverted to the war chests. It would be intriguing to follow the effect of political events

Crew cost analysis

| Year | Crew | Campaign | Cost in $A (1972) |
|---|---|---|---|
| 1194 | Rose | A | 515,250 |
| 1195 | Bronze | B | 373,250 |
| 1196 | Olive | C | 534,700 |
| 1197 | Green | D | 660,700 |
| 1198 | Bronze | E | 1,052,300 |
| 1199 | Red | F | 1,330,500 |
| 1200 | Bronze | Fx | 1,742,200 |
| 1201 | Rose | G | 1,816,200 |
| 1202 | Ruby | H | 1,289,800 |
| 1203 | Red | I | 1,631,000 |
| 1204 | Rose | J | 1,261,600 |
| 1205 | Bronze | K | 1,275,900 |
| 1206 | Scarlet | L | 1,630,600 |
| 1207 | Olive | M | 1,220,500 |
| 1208 | Rose | N | 1,082,800 |
| 1209 | Cobalt | O | 404.600 |
| 1210 | Red | P | 960,600 |
| 1211 | Rose | Q | 907,300 |
| 1212 | Bronze | R | 728,000 |
| 1213 | Scarlet | S | 1,123,400 |
| 1214 | Ruby | T | 1,121,600 |
| 1215 | Red | U | 1,588,300 |
| 1216 | Cobalt | V | 975,100 |
| 1217 | Bronze | W | 1,601,100 |
| 1218 | Olive | X | 1,364,100 |
| 1219 | Ruby | Y | 1,346,500 |
| 1220 | Bronze | Z | 1,251,800 |
| 1221 | Green | a | 855,400 |
| 1222 | Rose | b | 963,800 |
| 1223 | Bronze | c | 802,400 |
| | | **TOTALS to 1223** | **$A33,432,900** |
| | | + campaigns d-s | 4,620,000 |
| | | + stained glass | 4,290,000 |
| | | **GRAND TOTAL** | **$A42,429,000** |

on the cash flow of other great buildings, such as the well-known delay to the work at Reims during the upheavals in the town in the 1230s. Was the increase in tempo after the Fourth Crusade due to booty sent home by the victorious bishop?

However, the funds were raised, even by modern standards it was no mean achievement to sustain such a high level of activity for so many years – 11

campaigns in the first surge and 8 in the second – and says a great deal for the energy and resourcefulness of those responsible.

The curiously meagre amounts spent in the first four campaigns are worth examining in detail. According to the authors of the Miracles of the Virgin[17] the Bishop and Chapter had both promised after the fire to give "a not inconsiderable" part of their revenues to the new work for the first three years. Were their revenues not very large? Branner has shown[18] that the Chapter of Reims provided all the funds for the first few years, and only after 1213 looked to other sources to complete the work. Troyes, Westminster, Cologne and Speyer acted similarly. It was almost as if it was an accepted policy that the clergy had to begin the work from their own pockets before being allowed to appeal to the Pope for the special right to raise funds from elsewhere.

Yet it still seems strange that so little should have been spent. The Chartres Chapter was well-organised financially after a thorough reorganisation undertaken a few years earlier, and the diocese was one of the largest in France and apparently one of the wealthiest, yet only some half a million dollars was paid out from its revenues each year. Was this all it could afford? Perhaps the income of the Chapter was not as great as we have thought. Perhaps some of the funds were being diverted to the urgent rebuilding of the town itself, severely damaged in the same fire. Whatever the reason be, the evidence from the cash-flow chart is unmistakable; the funds available during the first campaigns were only one-third the amount the clergy were later to raise from other sources.

There are a number of assumptions in the quantities and rates which may affect this cost calculation. The footings may have been deeper than we allowed for, and the cost of the foundation walling may have been greater. With some exceptions, most cathedrals rest on foundations only few metres below ground and on this basis, plus the scanty information from earlier test holes dug round the building, we believe the levels, and the consequent tilt, to be accurate. Even if the footings had been taken down as far as another four metres, the extra cost would have been little more than $6,300,000, which could have delayed the work by up to twelve months, and perhaps even reduced the amount of money needed in the first three years.

The cash-flow chart could be re-arranged, though it would involve just as many assumptions as in the method we chose. One of the unreal aspects of the method we used is that we divided the time spent on the building equally among the teams, irrespective of the amount each spent. To compensate we re-arranged the times for each campaign on a cost-per-month basis that assumed that productivity per team was constant, which would not have been unlikely. We have no way of knowing how many men were employed in each crew, though it would be a fair guess that some crews would be large and some medium-sized but none small, for the small contractor would not have had either the knowledge or the expertise for such a complex job. We decided to ignore team size and presume for this calculation that there would be no fluctuation in productivity.

We divided the total cost of all the programmes by the number of years and spread the work evenly over the whole period. In the cost-per-month basis we inserted an arbitrary gap of four months between each campaign, and then apportioned the work on a monthly basis to see if it made any significant changes to the picture produced by the earlier by-the-year method.

The only important conclusion was that the first four small campaigns neatly fit into the first three years, while the two great programmes of F and G extended over almost three years. Besides that, the average dating remained very close to that chosen by the more direct one-year-per-campaign method.

The Cobalt-O team is by both methods still in 1209, they year before the Fourth Crusade, while some of the other teams have slipped a little forward or backward without affecting the picture by more than a few months. This comparison shows that further refinement would be pointless.

Though there is no way of knowing the size of each team, we found we could assess the average number of men employed from the figures we have. Nearly every material used came out of the ground or from the forests and therefore had to be hewn, axed for quarried by hand. The bulk of the cost on the job was for labour, employed by the Chapter through the organisations provided by the masters. We can safely assume that 80 percent of the masters' costs went in paying for labour, and only 20 percent for purchasing materials from outside such as lead and iron, for the right to fell timber, for wear and tear on carts and oxen, and so on. From the calculations the average annual expenditure was $28,300,000, or $2,400,000 per month.

On average Australian wage rates, including holidays and insurance, this sum would engage 270 men, comprising those working on the site, those working at the quarry face, the carters, the woodcutters in the forest, the skilled carvers and sculptors in the site shops, and those laying the stone-work. It was a large force of men to engage, pay and co-ordinate. A large city building project today seldom has more than 150 men at a time on the job, though there may be short periods, towards the end of the work, when in the factory and on the site over 400 may be involved. Moreover, in modern projects the workforce is increased for constructing the services, lifts, air-conditioning, electrical fitments and so on. At Chartres there would only have been a few ancillary teams, for the stained glass and the choir stalls, that have not been included in this calculation. These supplementary teams would not have been numerous enough to have made a significant difference.

Many of the men in the workforce could have been local. Besides the carters and their teams of oxen, the masons would have used local labourers to mix and carry the cement, to help move the stone blocks and the timbers, to work the cranes, and other unskilled tasks. After a time, some of the villagers or townsfolk would have become proficient in quarrying and roughing the stones, and much of the detritus left at Bechère could be off-cuts from roughing-in before the stones were finished by the professionals. I cannot be exact, but from my experience and from watching building work in Asia and Africa, where modern industrial methods do not exist, I believe that 60 percent of the total workforce could have been local, and perhaps a greater proportion if some men with building skills had been taken on to augment the permanent crews.

This leaves about a hundred men in each team who moved from job to job and formed the permanent core of skilled men who followed their master from site to site. This core of men was no larger than for a fair-sized circus today and is not an unfair comparison. They were itinerants, with stronger loyalties to their mates than to client, region or lord, and most strongly attached to the master mason himself, whose role must have approached that of a feudal chieftain.

If from among 270 men we subtract 30 for carting and 20 for general work, such as on cranes and cleaning up, then the remaining 220 could be reasonably split up into sixteen or so separate crews, each under its own leading hand. The last-named, together with the master, his foreman and assistant, and a draughts-man would have made an executive of about 20 key men without whom no work could be begun or completed. Indeed, these contractors were themselves teams of skilled men, well-known to one another over many decades of working together on common problems, and forming a clear hierarchy of responsibilities culminating in the master

himself. Scholars often lose sight of the essential teamwork that underlies all these great works.

Some day we may find enough information to assess the effect on a small community of employing so many "foreigners" and their oxen for long periods. Also, what was the effect on the attitudes and prosperity of the local community of suddenly having injected into it so much outside money for so long? And what happened after a generation had had time to become attuned to this subsidy when the project was finished and the funds stopped? Was everyone satisfied with a probable return to farming and its modest returns, or did the more adventurous, feeling a sense of unfulfillment, slip away to other building sites or to the cities? The money which came into small agricultural communities can be likened to the flow of tourist cash into simple economies like Samoa or Bali, whose barter and low-cost exchange give way to coins obtained by selling to or catering for the tourists; so that the acquisition of money becomes more important than the old seasonal way of life. To some extent the very act of building the cathedrals were the highest expression of the ideals of their period, but in being built and paid for they must have so modified the fabric of medieval society that later generations gradually adopted new values and different forms of expression.

1. Louis Salzman, *Building in England down to 1540,* Oxford, 1952; John Harvey, *The medieval architect*, London, 1972; Douglas Knoop and G. P. Jones, *The mediaeval mason,* Manchester, 1933
2. John James, *The contractors of Chartres*, Wyong, ii vols. 1979-81; John James, Chartres, *Les constructeurs,* Chartres, iii vols. 1977-82
3. James, *ibid*.
4. Jan van der Meulen, "Recent literature on the chronology of Chartres cathedral", *The Art Bulletin*, xlix 1967, 152-172..
5. John James, "40 Funding",.*In Search of the unknown in medieval architecture,* 2007, Pindar Press, London,
6. The equivalent currency values of one Australian dollar in December, 1972 were: $0.49 Sterling, 1.1963 USA, 3.8220 German, 4.5250 Swiss, 5.6570 Swedish, 5.9950 French, 76.00 Spanish and 696.05 Italian.
7. A Lewis bolt is a wedge-shaped steel toggle that fits into an expanding hole drilled into the upper surface of the stone.
8. Van der Meulan made this suggestion. For Fulbert's church John James, "La construction du narthex de la cathédrale de Chartres", *Bulletin de la Société Archéologique d'Eure-et-Loir,* lxxxvii 2006, 3-20.
9. Vault shown in the 11th-century drawing of the old building reproduced in Robert Branner, *Chartres Cathedral,* New York, 1969.
10. John Fitchen, *The construction of Gothic cathedrals. A study of medieval vault erection*, Oxford, 1961.
11. In and after 1215 for the nave aisles (after the temporary roof was raised), 1218 for some of the clerestory (about the time the main roof was being assembled), 1224 for the southern rose (window), and 1230 for the northern. James, *ibid*..
12. Estimates were discussed with Henri Lorin and Gabriel Loire, both with stained glass workshops in Chartres.
13. Van de Meulan, *ibid*. Louis' generosity may have provided a large part of the funds during his lifetime.
14. Janet Snyder, "Written in Stone: the impact of the properties of quarried stone on the design of medievel sculpture", *Avista Forum Journal,* xiii 2003, 1-6.
15. John James, "An investigation into the uneven distribution of churches in the Paris Basin, 1140-1240", *Art Bulletin*, lxvi 1984, 13-46..
16. Van de Meulan, *ibid*; and Branner, ibid.
17. Branner, *ibid*
19 Robert Branner, "Historical Aspects of the Reconstruction of Reims Cathedral", *Speculum,* xxxvi 1961, 23-37 25.