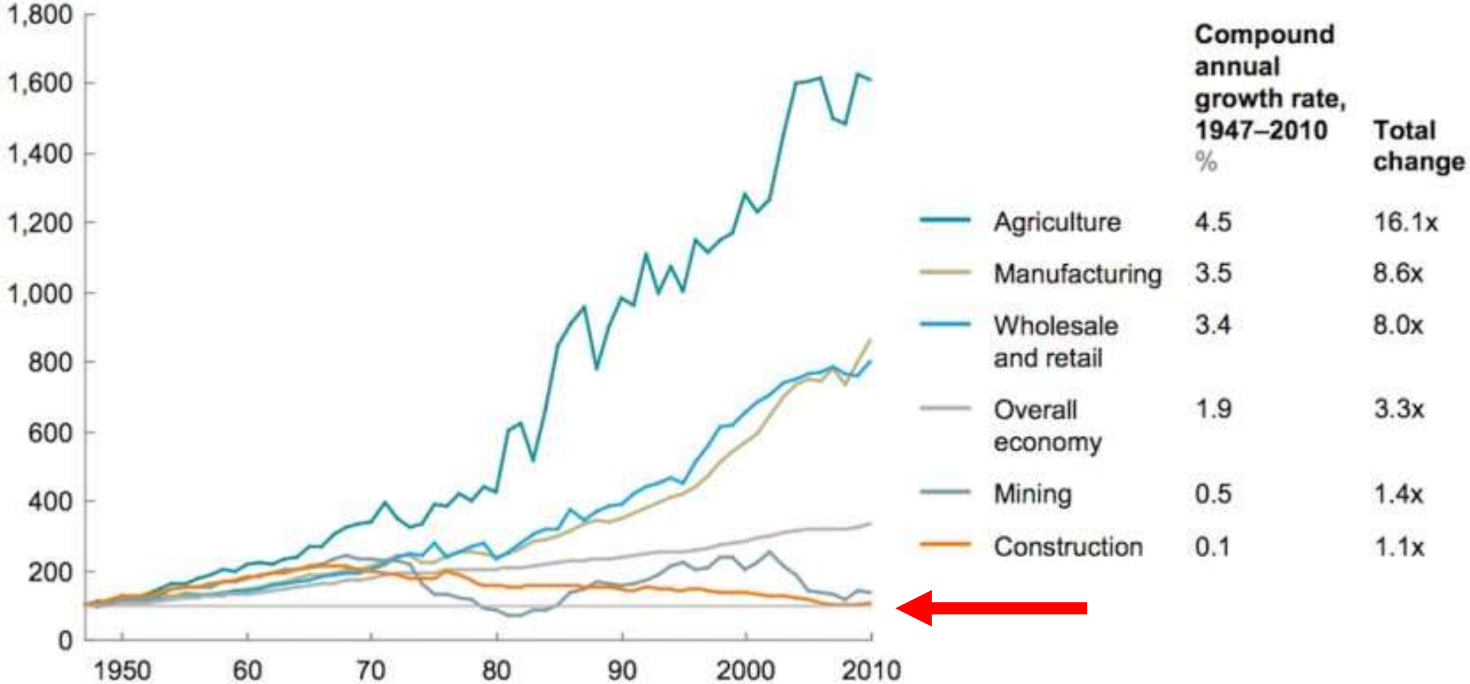
# Chapter 20

## IMPROVING PRODUCTIVITY AND PERFORMANCE

**In the United States, labor productivity in construction has declined since 1968, in contrast to rising productivity in other sectors**

**Gross value added per hour worked, constant prices**

Index: 100 = 1947




**Many sectors have transformed and achieved quantum leaps in productivity; construction has changed little, limiting productivity gains**

Key advances, 1947–2010

| Agriculture | Manufacturing | Retail | Construction |
|---|---|---|---|
| Leveraged scale through land assembly and automation; deployed advanced bioengineering to increase yields | Implemented entirely new concepts of flow, modularized and standardized designs, and aggressively automated to increase production | Utilized scale advantages and cutting-edge logistics to provide affordable goods to the masses | Limited improvements in technological capabilities, production methods, and scale |

SOURCE: World KLEMS; BLS; BEA; McKinsey Global Institute analysis

# State of the Industry

- The serious decline in U.S. construction industry productivity during the 1960s and 1970s led the Business Roundtable to conduct its Construction Industry Cost Effectiveness (CICE) study.
- This study, completed in 1982, was probably the most comprehensive study ever made of the U.S. construction industry.

# State of the Industry

- Although the study found that the U.S. construction industry faced a number of problems in remaining competitive in the international construction market, it concluded that the majority of problems could be overcome by improved management of the construction effort (i.e. increase efficiency).

- At the project management level, the study discovered inadequate management performance in a number of areas which include:
  - construction safety,
  - control of the use of overtime,
  - training and education,
  - worker motivation and
  - failure to adopt modern management systems.

**What is Productivity?**

"Productivity" means the output of construction goods and services per unit of labor input.

## Tools for Better Management

- A number of studies, including the CICE study, have shown that most on-site delays and inefficiencies lie within the control of management (Why?).
- (Because) Management is responsible for planning, organizing, and controlling the work.
- If these management responsibilities were properly carried out, there would be few cases of workers standing idle waiting for job assignment, tools, or instructions.
- One of the major tools for improving construction productivity is work improvement; that is, the scientific study and optimization of work methods.

- Workers' physical capacity, site working conditions, morale, and motivation are important elements in determining the most effective work methods and the resulting productivity for a particular task.
- Other techniques available to assist the construction manager in improving construction productivity and cost-effectiveness include:
  - network planning methods,
  - economic analyses,
  - safety programs,
  - quantitative management methods (linear programming),
  - simulation, and the use of computers.

# WORK IMPROVEMENT

- An important component of work improvement is preplanning, that is, detailed planning of work equipment and procedures prior to the start of work which include:

  1. Physical models and traditional work improvement techniques may be used in the preplanning process.

  Traditional work improvement techniques include:

  2. Time studies,
  3. Flow process charts,
  4. Layout diagrams,
  5. Flow diagrams, and
  6. Crew balance charts

# 1. Physical Models

- Models are often used for large and complex projects such as power plants, dams, and petrochemical process plants to check physical dimensions, clearance between components, and general layout.
- Computer graphics and computer-aided design (CAD) can perform similar functions faster and at lower cost than can physical models or other manual techniques.

# 1. Physical Models

# 2. Time Studies

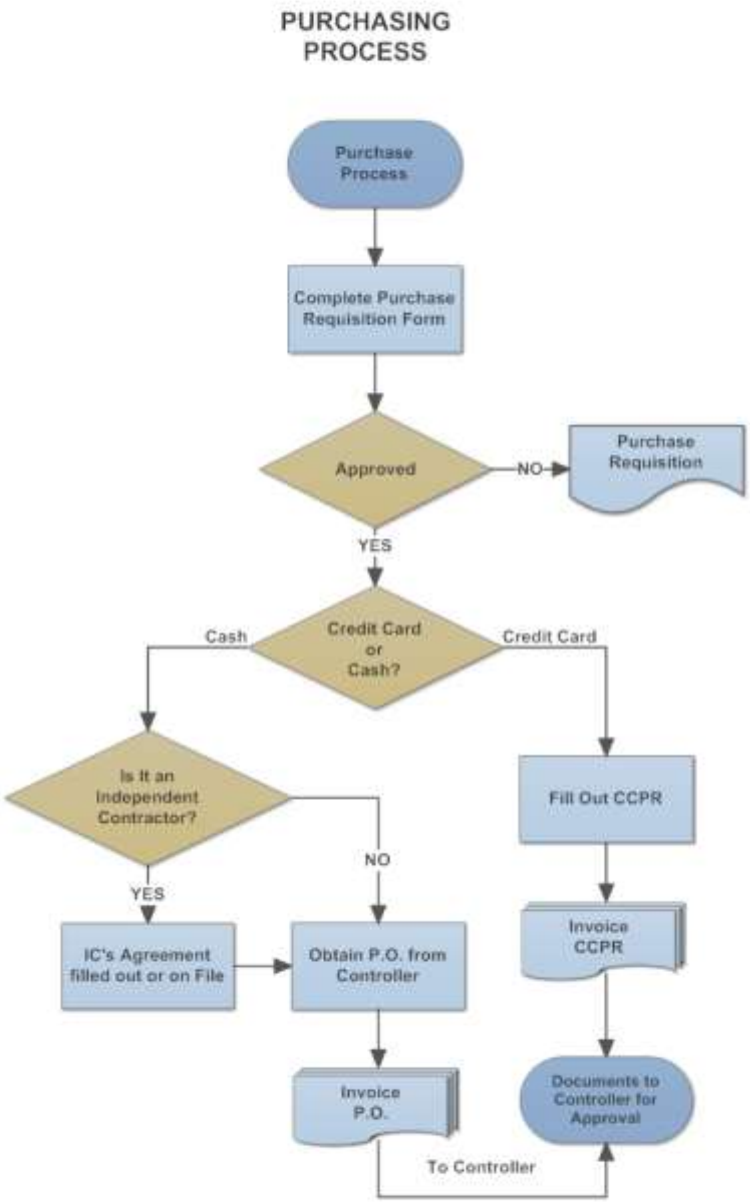
- Time studies are used to collect time data relating to a construction activity for the purpose of either statistical analysis or of determining the level of work activity.
- It is important that the data collected be statistically valid.
- Work sampling is the name for a time study conducted for the purpose of determining the level of activity of an operation.
- A study of a construction equipment operation, for example, may classify work activity into a number of categories, each designated as either active or nonworking.

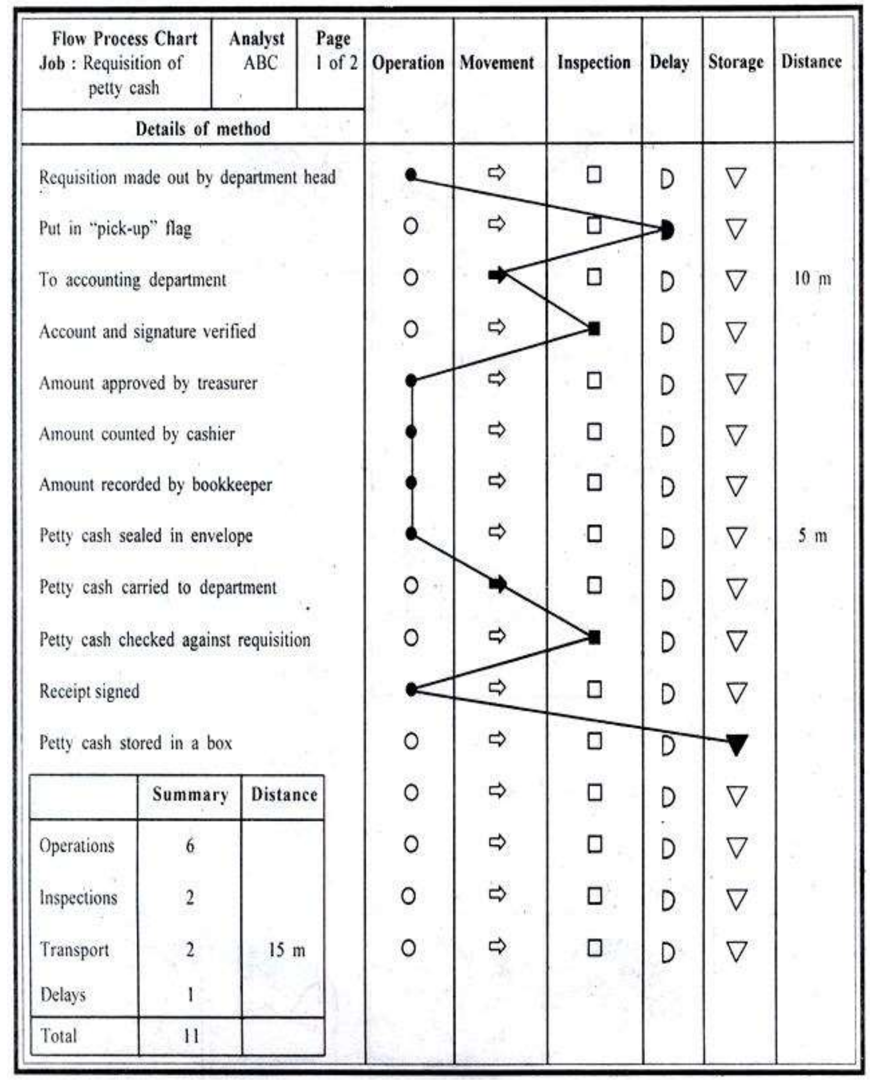
- Sampling for labor effectiveness may also divide observations into categories such as effective work, essential contributory work, ineffective work, and nonworking.
- Analysis of work by category will again assist management in determining how labor time is being utilized and provide clues to increasing labor effectiveness.
- Although time studies are traditionally made using stopwatches and data sheets, there is growing use of time-lapse equipment for conducting work improvement studies on construction projects provides several advantages over stopwatch studies.
- Modified super-8mm cameras and projectors provide a relatively inexpensive method of recording and analyzing time-lapse film.

# 3. A flow process chart

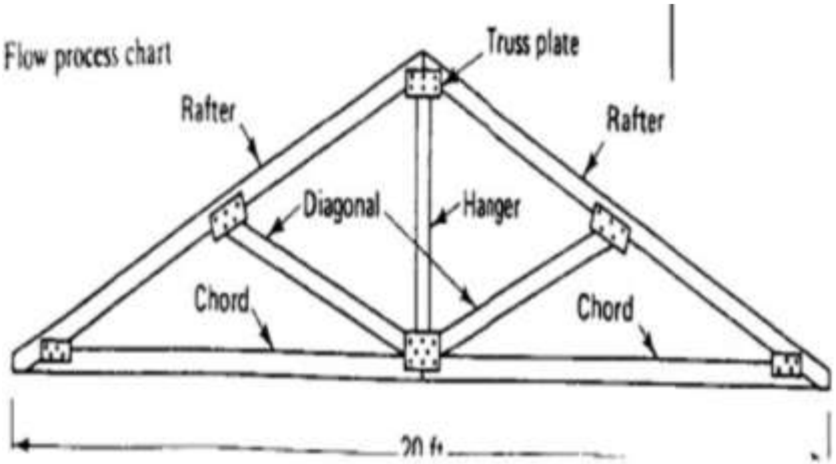
- A flow process chart for a construction operation serves the same purpose as does a flowchart for a computer program.
- That is, it traces the flow of material or work through a series of processing steps (classified, as an example, as operations, transportation, inspections, delays, or storage).
- Depending on the level of detail, it usually indicates the distance and time required for each transportation and the time required for each operation, inspection, or delay.
- From the chart the manager should be able to
  - Visualize the entire process and
  - To tabulate the number of operations, transportation, inspections, delays, and storage involved, and
  - The time required for each category.

# 3. A flow process chart



Flow process chart




| FLOW PROCESS CHART | NUMBER 101 | PAGE NO. 1 | NO. OF PAGES 1 |
|---|---|---|---|
| PROCESS: Assemble Truss | | | |
| MAN OR MATERIAL | | | |
| CHART BEGINS: Parts stack | CHART ENDS: Parts stack | | |
| CHARTED BY: J. Doe | DATE: 7/13 | | |
| ORGANIZATION: E Z Construction | | | |

| SUMMARY: ACTIONS | PRESENT NO. | PRESENT TIME | PROPOSED NO. | PROPOSED TIME | DIFFERENCE NO. | DIFFERENCE TIME |
|---|---|---|---|---|---|---|
| OPERATIONS | 10 | 137 | | | | |
| TRANSPORTATIONS | 9 | 90 | | | | |
| INSPECTIONS | 0 | | | | | |
| DELAYS | 0 | | | | | |
| STORAGES | 0 | | | | | |
| DISTANCE TRAVELLED (Feet) | 300 | | | | | |

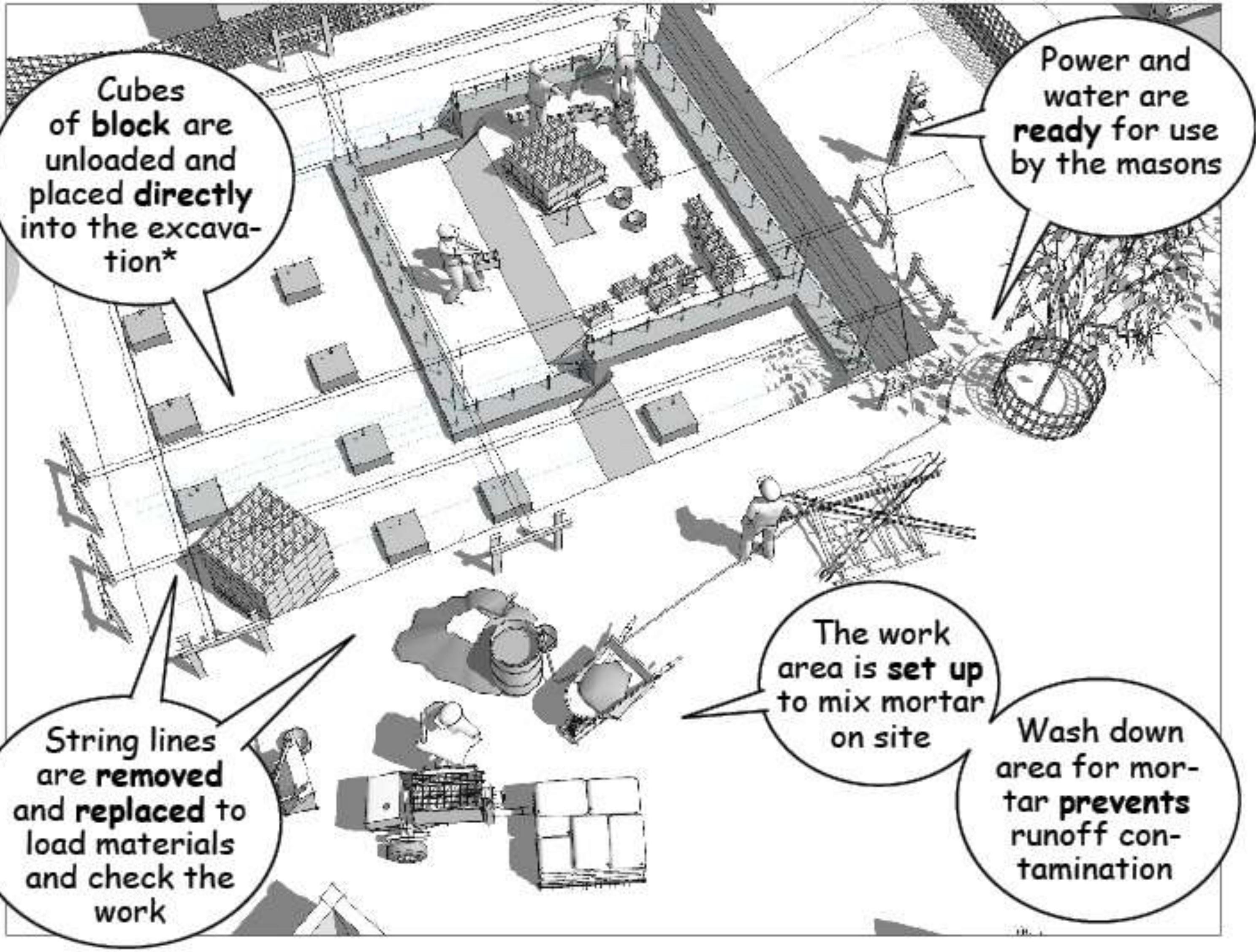
| DETAILS OF PRESENT / PROPOSED METHOD | OPERATION / TRANSPORTATION / INSPECTION / DELAY / STORAGE | DISTANCE IN FEET | QUANTITY | TIME (sec) | NOTES |
|---|---|---|---|---|---|
| 1 Remove chords from stack | ○◇□D▽ | | 2 | 3 | |
| 2 Transport chord to jig | ○◇□D▽ | 25 | 2 | 10 | |
| 3 Position chords in jig | ○◇□D▽ | | 2 | 5 | |
| 4 Return to parts stack | ○◇□D▽ | 25 | | 6 | |
| 5 Remove rafters from stack | ○◇□D▽ | | 2 | 3 | |
| 6 Transport rafters to jig | ○◇□D▽ | 25 | 2 | 10 | |
| 7 Position rafters in jig | ○◇□D▽ | | 2 | 5 | |
| 8 Return to parts stack | ○◇□D▽ | 25 | | 6 | |
| 9 Remove diagonals | ○◇□D▽ | | 2 | 3 | |
| 10 Transport diagonals | ○◇□D▽ | 25 | 2 | 10 | |
| 11 Position diagonals in jig | ○◇□D▽ | | 2 | 5 | |
| 12 Return to parts stack | ○◇□D▽ | 25 | | 6 | |
| 13 Remove hanger from stack | ○◇□D▽ | | 1 | 3 | |
| 14 Transport hanger to jig | ○◇□D▽ | 25 | 1 | 10 | |
| 15 Position hanger in jig | ○◇□D▽ | | 1 | 5 | |
| 16 Fasten truss plates | ○◇□D▽ | | 12 | 85 | |
| 17 Remove truss from jig | ○◇□D▽ | | 1 | 20 | |
| 18 Trans & stack truss | ○◇□D▽ | 50 | 1 | 15 | Using forklift |
| 19 Return to parts stack | ○◇□D▽ | 75 | | 17 | |
| 20 | ○◇□D▽ | | | | Cycle time |
| 21 | ○◇□D▽ | | | | = 227 sec |

**Figure 20–1** Flow process chart.

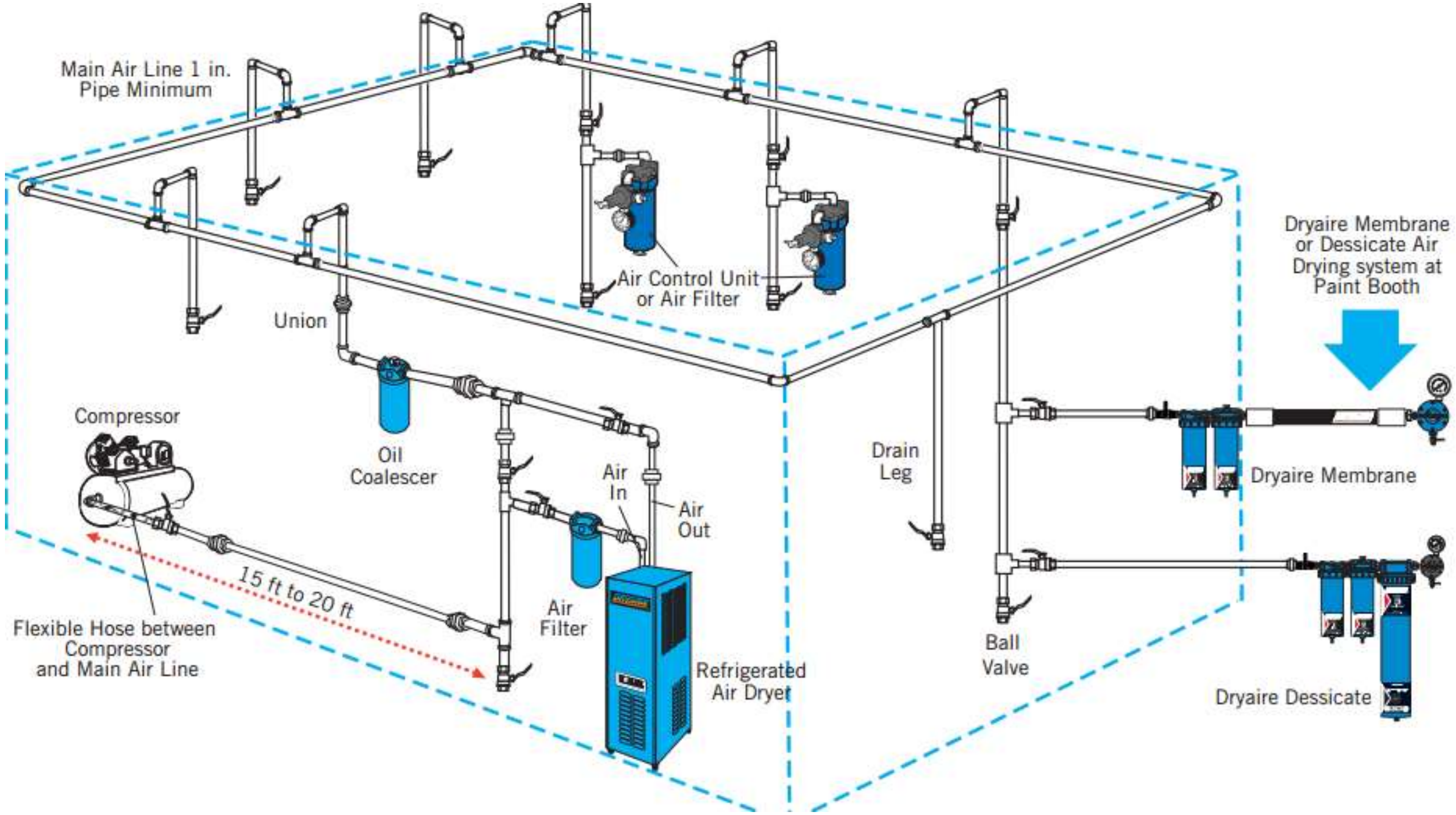
# 4. Layout Diagrams

- A layout diagram is a scaled diagram that shows the location of all physical facilities, machines, and material involved in a process (i.e. satellite picture).
- Since the objective of a work improvement study is to minimize processing time and effort, use a layout diagram to assist in reducing the number of material movements and the distance between operations.

# Layout Diagrams



# Layout Diagrams



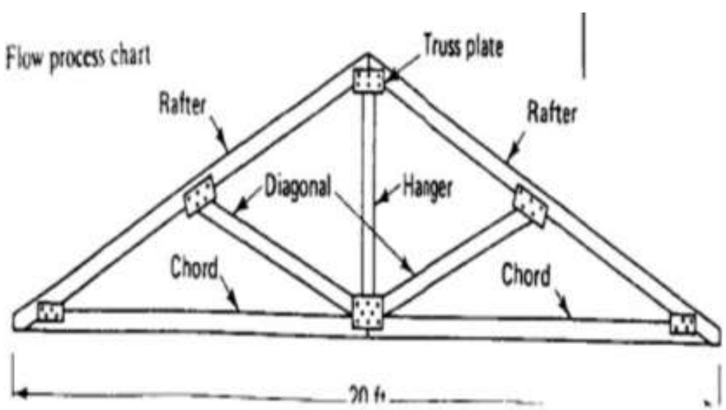
# 5. A flow diagram

- A flow diagram is similar to a layout diagram but also shows the path followed by the worker or material being recorded on a flows process chart.
- The flow diagram should indicate the direction of movement and the locations where delays occur.
- Step numbers on a flow diagram should corresponded to the sequence number used on the corresponding flow process chart.

- flow process charts, layout diagrams, and flow diagrams must be studied together for maximum benefit and must be consistent with each other.
- Since layout diagrams and flow diagrams help us to visualize the operation described by a flow process chart, these diagrams should suggest
  - jobs that might be combined,
  - storage that might be eliminated, or
  - transportation that might be shortened.

# 6. Crew Balance Charts

- A crew balance chart uses a graphical format to document the activities of each member of a group of workers during one complete cycle of an operation.
- A vertical bar is drawn to represent the time of each crew member during the cycle.
- The bar is then divided into time blocks showing the time spent by that crew member on each activity which occurs during the cycle.
- The crew balance chart enables us easily to compare the level of activity of each worker during an operation cycle.



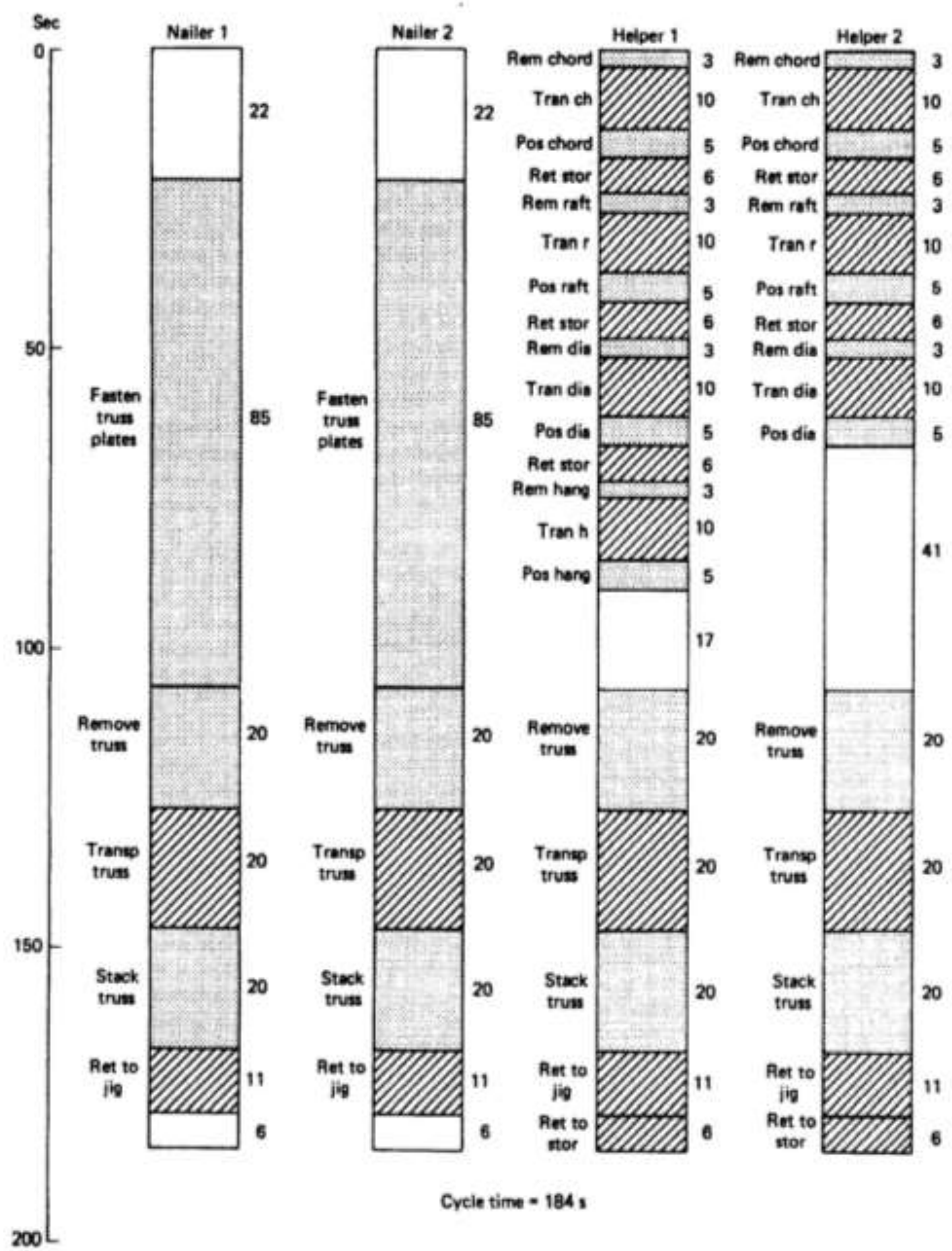



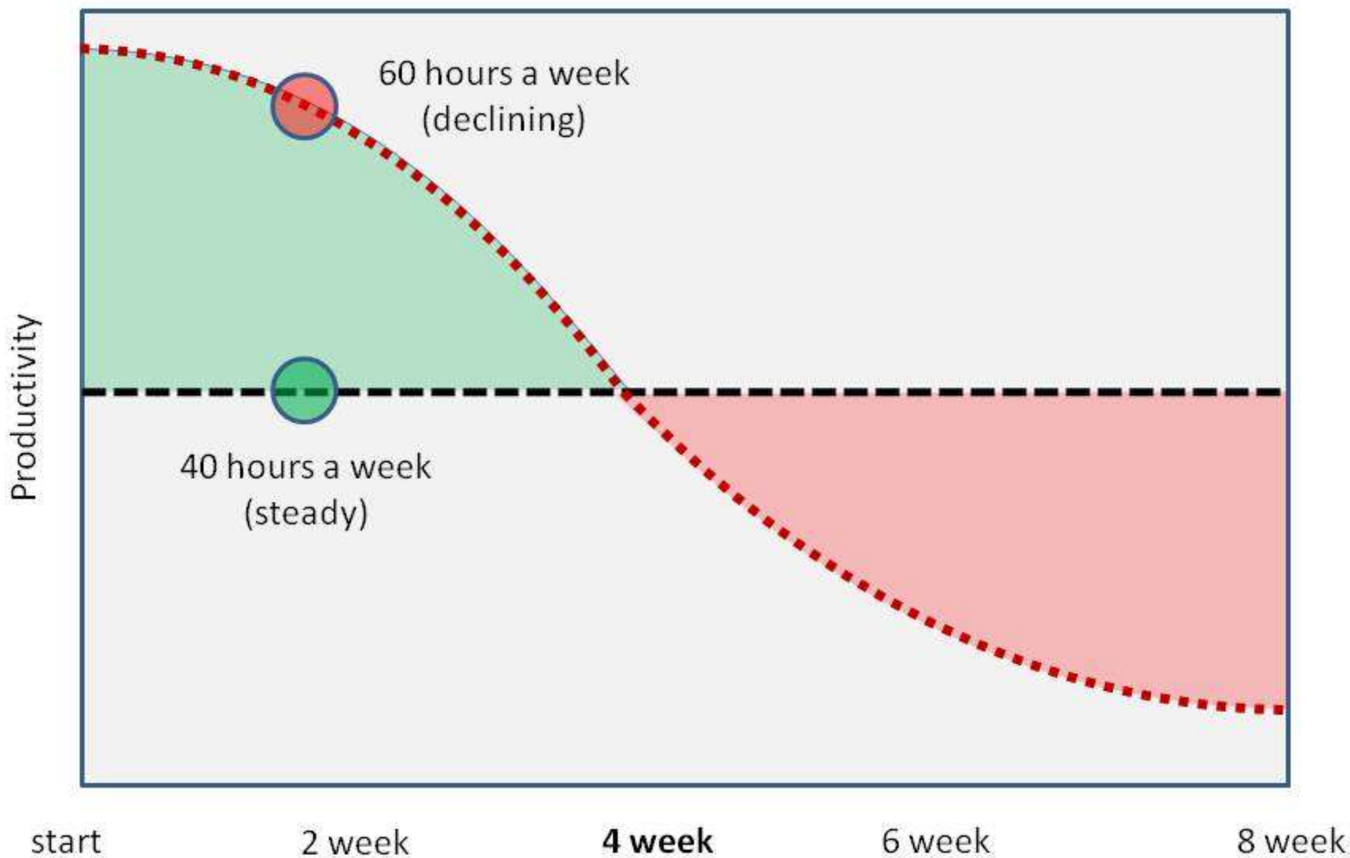

**Figure 20-3** Crew balance chart.

# Human Factors

- Workers who are fatigued, bored, or hostile will never perform at an optimum level of effectiveness.
- Some major human factors to be considered include environmental conditions, safety conditions, physical effort requirements, work hours, and worker morale and motivation.
- Attempts at sustained higher levels of effort will only result in physical fatigue and lower performance.
- Physical work requirements should be adjusted to match worker capability.

- Studies have shown that worker productivity is seriously reduced by sustained periods of overtime work.
- When the premium cost of overtime is considered, it is apparent that the labor cost per unit of production will always be higher for overtime work than for normal work.
- Worker morale and motivation have also been found to be important factors in construction worker productivity.
- Factors inhibiting craft productivity , nonavailability of material was the most Significant, followed by nonavailability of tools, and the need to redo work.

# Graphing productivity and overtime



# Some of the worker demotivators identified by the study.

- Disrespectful treatment of workers.
- Lack of sense of accomplishment.
- Nonavailability of materials and tools.
- Necessity to redo work.
- Discontinuity in crew makeup.
- Confusion on the project.
- Lack of recognition for accomplishments.
- Failure to utilize worker skills.
- Incompetent personnel.
- Lack of cooperation between crafts.
- Overcrowded work areas.
- Poor inspection programs.
- Inadequate communication between project elements.
- Unsafe working conditions.
- Workers not involved in decision making.

# Some of the worker motivators identified in the study

- Good relations between crafts.
- Good worker orientation programs.
- Good safety programs.
- Enjoyable work.
- Good pay.
- Recognition for accomplishments.
- Well-defined goals.
- Well-planned projects.

# Technology in Construction

Current and Future Trends

## Areas of Technology Advancement in Construction

### Data Collection and Analytics

- Laser Scanning (LiDAR)
- Drones
- Big Data
- Artificial Inelegance

### Building Information Modeling

- Design
- Construction
- Maintenance and Operation

### Construction Wearables and Augmented Reality

- Smart Personal Protective Equipment (PPE) (hats, boots, gloves)

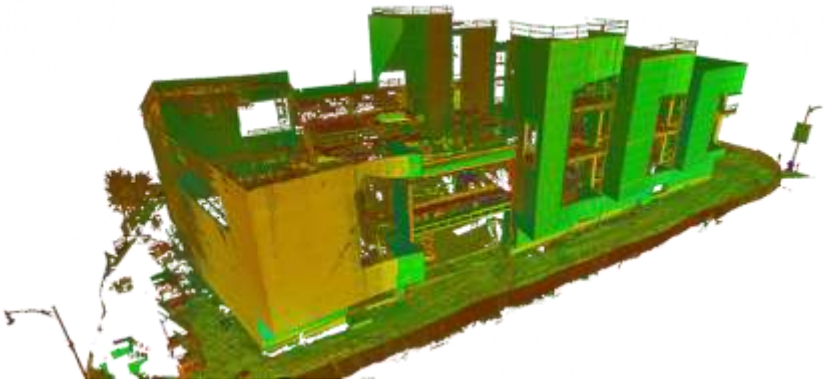
### Construction Robots and 3D Printing

Data Collection and Analytics

# Laser Scanning (LiDAR)

Can enhance:

- Ground mapping
- Construction progress monitoring
- Building inspection



# Drones

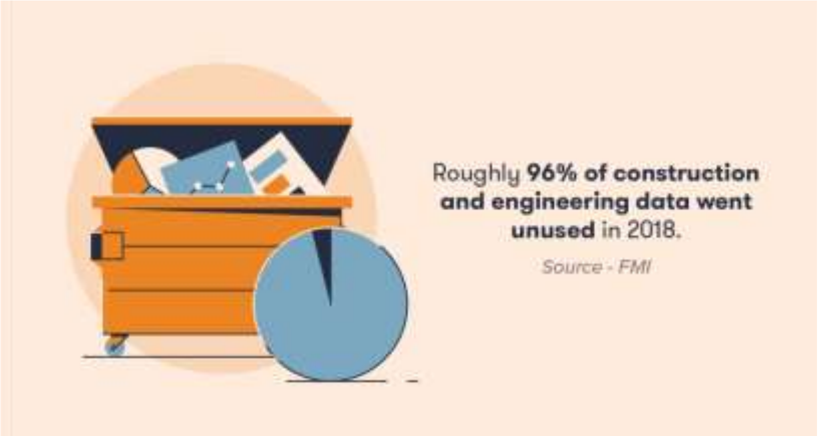
Can be used in:

- **Topographic maps:**

  Mapping is vital during the preconstruction phase. reducing mapping costs by as much as 95%.

- **Equipment tracking**
- **Security surveillance**
- **Safety monitoring**

Data Collection and Analytics




# Big Data and Artificial Inelegance

- New data collection technologies are generating enormous amount of raw data that can be utilized.

**Examples of areas where Big Data and AI can be used:**

- **Improved safety:** analyzing job site data (e.g., drones, wearables, etc.) and identifying risks and safety violations
- **Decreased costs:** analyzing past projects and identifying inefficiencies and propose more effective timelines
- **Better design:** it can improve building design aspects by exploring hundreds of variations

Building Information Modeling

# BIM

- Evolution of CAD:

**2D** Digital drawing → **3D** Modeling purely for visualization purposes → **BIM** Information-loaded models → **5D** Linked with Time and Cost

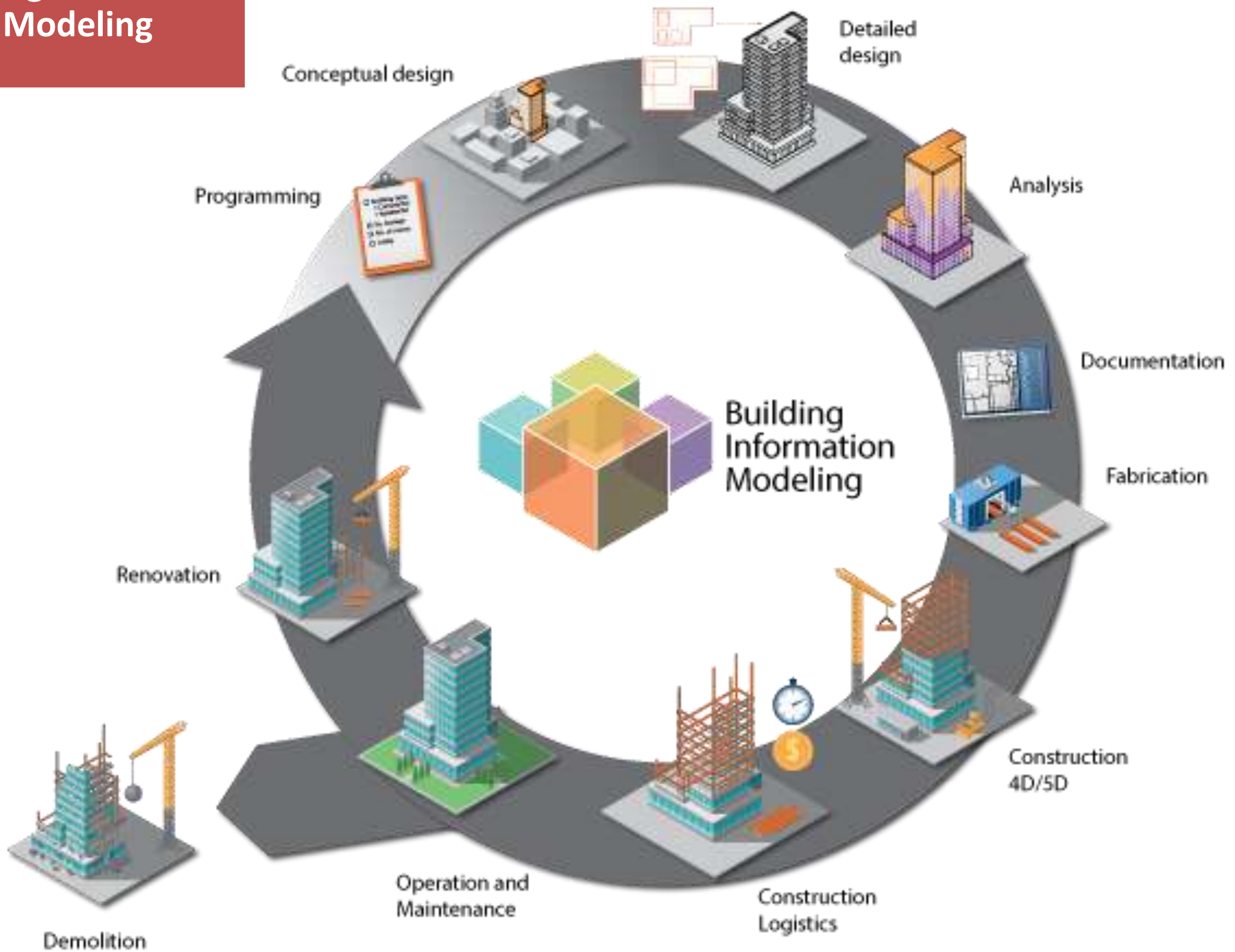
- Uses Object-Oriented Programming where each element is an ***object*** (not a just a drawing)
- Objects have characteristics and can be linked to other data (e.g., material, cost)
- Single, central model where changes to objects are reflected in all views (we are not working with a set of drawings!)

Building Information Modeling

## <u>Some benefits of BIM:</u>

- Improved **visualization**
- Increased coordination of construction **documents**
- Linking of vital information such as vendors for specific materials, location of details and quantities required for estimation and tendering
- Automatic **quantity take-off**
- Detection of **clashes (design errors)** and **constructability** analysis
- Complete as-built model for **operating and maintenance**

# Building Information Modeling



## Construction Robots

Still away from dominating the construction industry. But some forms of robotics are being used in construction (Ex: repetitive jobs).

**Example: brick laying**

Construction Robots and 3D Printing

## 3D Printing

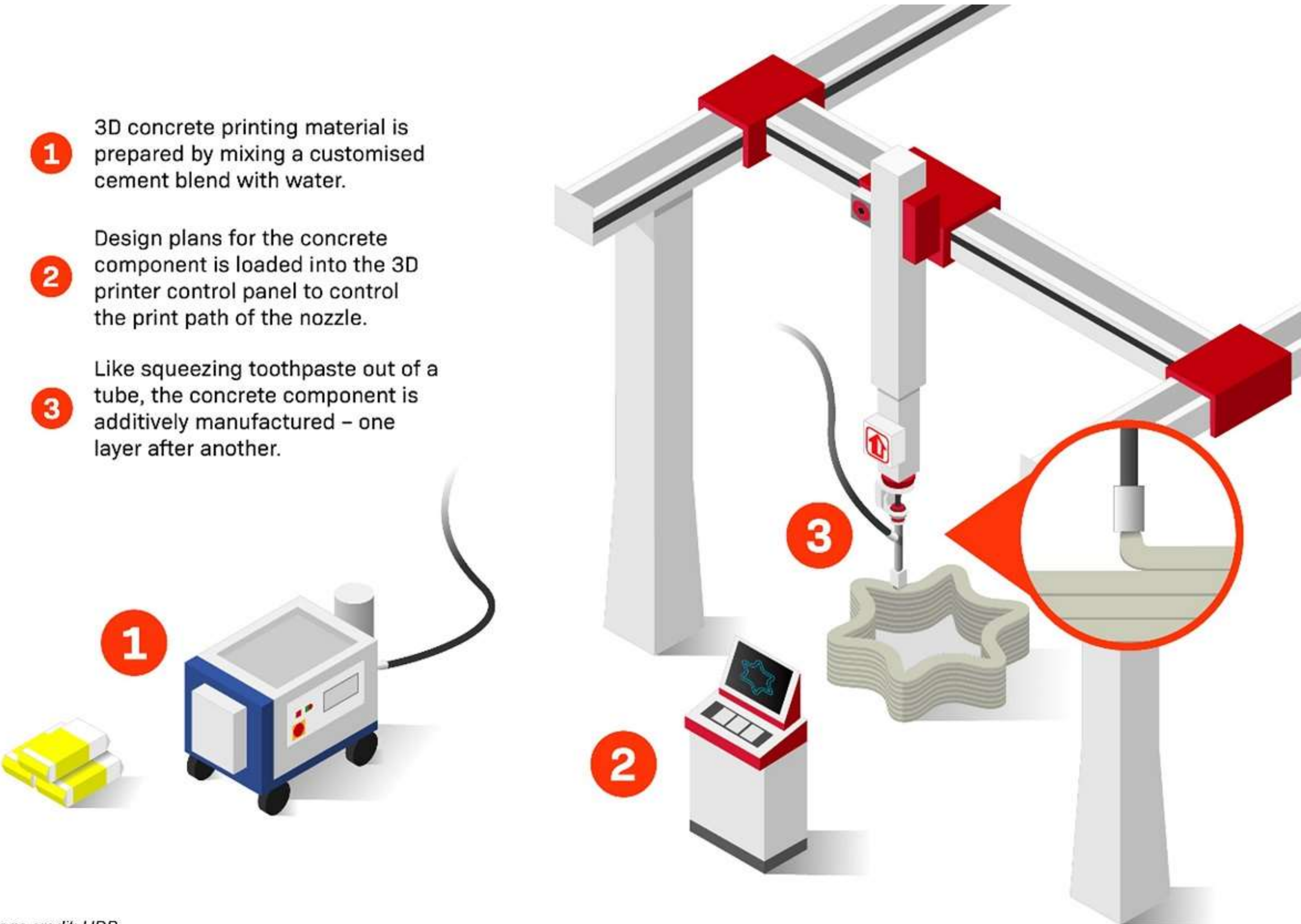



*Image credit: HDB*


شارة البناء المتقدم
حافز فخري لزيادة تبني أساليب بناء الجيل الرابع وتعزيز جاذبيتها في المشاريع السكنية، ويقدم كتكريم رسمي من قبل مبادرة أساليب البناء الحديث
البناء الحديث
Modern Construction
4.0
عن الشارة
شعار رقمي
يستخدم على المطبوعات والمستندات الرقمية
يستخدم كتوقيع البريد الإلكتروني
تحفيز تبني استخدام تقنيات البناء من الجيل الرابع
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سرعة الإنجاز
زيادة التنافسية بين المطورين العقاريين والمقاولين
800
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تنتهج تقنيات بناء الجيل الرابع خلال عام 2021
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المؤهلون للحصول على الشارة
المكاتب الاستشارية
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