PRO 204 – Modeling Prototyping

MODELMAKING

Larger parts can be made with some planning by splitting the file into parts, which are then printed separately and joined together after printing. Given the fairly high cost of the materials, this is often where it becomes important to consider less expensive modelmaking routes that involve an approach other than rapid prototyping.

Material Cost

There is generally a trade-off between cost, surface quality and material strength. Less expensive materials might be suitable for certain applications where appearance rather than strength or flexibility is of importance. The cost can be a significant issue if the model is large. The cost of the material also needs to be considered in terms of cost of support structure material (typically a secondary material) and any secondary processing, such as secondary material infusion for strength.

Level of Finish

There is both time and cost associated with the manual labour involved in finishing parts. This again is highly dependent on the purpose of the prototype. If the model is made simply to test fit and function, very little or no finishing is necessary. The most time-consuming models tend to be the high-fidelity appearance models used for communication. This is where it makes sense to have the best possible surface quality to begin with.

Service bureaus tend to offer various levels of finishing. The basic level tends simply to include removing the support structures and perhaps bead-blasting the parts. A higher level of finish might include manual sanding to remove staircasing. A still higher level might include further sanding and primer ready for paint. If required, the service bureaus will completely finish the parts to any level of production quality appearance, including high-quality surface paint or electroplating.

Students can accomplish very high-quality results by using fillers and paint: water-based products are usually the safer option. Chapter 18 on painting (page 154) shows how to finish a rapid prototype similar to those below to a smooth glossy finish, such as this painted metallic finish (using water-based products).

Sanding, filling and painting will produce very good cosmetic surfaces, as shown on the left. The inside of the part on the right shows what it would look like if painted without extra preparation.

Powder-Based Technology

These types of system use a powder-based substrate that is deposited in thin additive layers and then hardened only in the area defined by the part's cross section. The extra powder surrounding the parts presents some inherent advantages. First of all it serves as a natural support structure. Secondly, the extra powder is simply reused, thereby minimizing material usage. The powder also allows parts to be nested easily, without the need for more complex support structures to bridge the parts. Powder-based materials are used in industrial as well as desktop 3D printer systems, but the process and materials used in the two systems shown in this book differ markedly from each other.

Industrial System – Selective Laser Sintering (SLS)

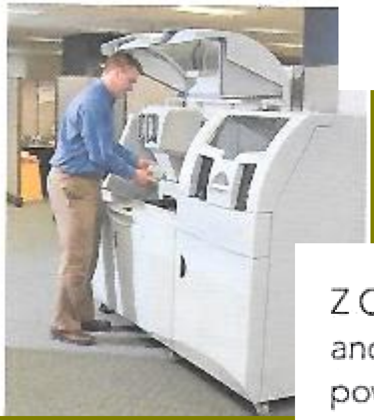
Selective Laser Sintering (SLS) is a rapid prototyping technology sold by 3D Systems Corporation, South Carolina. The technology has been around since the early 1990s and is therefore one of the pioneering methods of rapid prototyping. These industrial RP systems will produce parts in a wide range of materials that are selectively sintered with a laser. It works by depositing a thin layer of powder material in a build chamber, which is then selectively sintered (fused with heat) from a CO_2 laser. The process is continued layer by layer until the part is complete. The materials include a variety of consumer- and engineering-grade plastics: polypropylene for living hinges, glass-reinforced plastics for strength, and elastomeric materials to produce anything from shoe soles to gaskets. SLS also produces durable plastic and metal parts through direct laser sintering that are also suitable for end use applications.

3D Printer – Z Corporation

Z Corporation has offered powder-based 3D printing since the mid-1990s. The basis of its technology is the use of consumer inkjet printing on top of a layer of plaster powder. As the inkjet prints the cross section it applies a binder that holds the printed area together. This is repeated in fine increments, by automatically lowering the build volume and applying a new fine layer of plaster. Thanks to a multiple printhead approach, each layer prints very quickly, allowing a high vertical build speed. Containment of the fine powder is a consideration, since parts need to be physically removed from the powder tray and cleaned of excess powder.

As the printers increase in size and cost, they also tend to offer a higher throughput, better accuracy and more colours.

The sPro 240 Selective Laser Sintering machine is used to create parts in a range of consumer and engineering grade materials.



Z Corporation's entry-level ZPrinter® 150 (far left) and largest ZPrinter® 650 (left) both use plaster powder and inkjet technology to produce parts quickly and cost-effectively.

The simple and low-cost material is excellent for conceptual modelmaking, but the strength of the parts as printed is somewhat limited in functional applications. The strength can, however, be increased through post-processing. Plaster parts have minute air pockets that can be infiltrated with secondary materials to provide added strength. Salt water, wax, cyanoacrylate glue (super glue) or two-part epoxy can be used for plaster infiltration. Z Corporation produces three different infiltrants. Water Clear is a saltwater-based infusion system that models are dipped into. For stronger and more functional prototypes the Z-Bond cyanoacrylate infiltrant has been developed, and for even more structural applications Z-Max epoxy-based infiltrant is used.

ZPrinter® parts can be produced in a full range of colours. Shown are Reebok DMX shoe soles (right) and Sea-Doo® Seascooter™ underwater propulsion system (below) prototypes printed on a ZPrinter®.

The printed part is removed from plaster build tray.

Parts are infused with salt water, cyanoacrylate or two-part epoxy depending on the intended use and application.

Solid-Based Technology

The predominant solid-based technology is known as fused deposition modelling (FDM), a process developed and patented by Stratasys Inc. This process works by feeding a thin filament of ABS into a heated extrusion head. FDM is available both as high-end industrial machines and smaller 3D printer systems.

Industrial – Fortus

The Fortus™ range of FDM equipment from Stratasys can produce large structural parts even for small-scale manufacturing or industrial fixtures. Parts can be made in ABS, polycarbonate or Ultem engineering-grade plastic.

3D Printer – Dimension uPrint

Stratasys also produces the Dimension uPrint® range of 3D printers (known as HP Designjet 3D printers in Europe) for in-house prototyping. These are extremely easy to use as the materials are held in print cartridges, which can be replaced on the fly to change colour or add material. There is a separate cartridge for the material used for the support structure.

Depending on the machine model, the support structure is either an easy breakaway material or a water-soluble material. The water-soluble type of structure is more suitable for thin-walled and delicate parts that may be damaged in the breakaway process.

Support structures are either washed away in a special water-based solution or simply peeled away in the case of the breakaway system.

Small-scale production of parts in real plastics saves money on injection-mould tooling.

3D printers use real ABS plastic to

ABS material spool cartridge loaded into the 3D printer. A similar cartridge exists for the support structure material.

Lawnmower prototype made by Fortus™ FDM.

Liquid-Based Systems

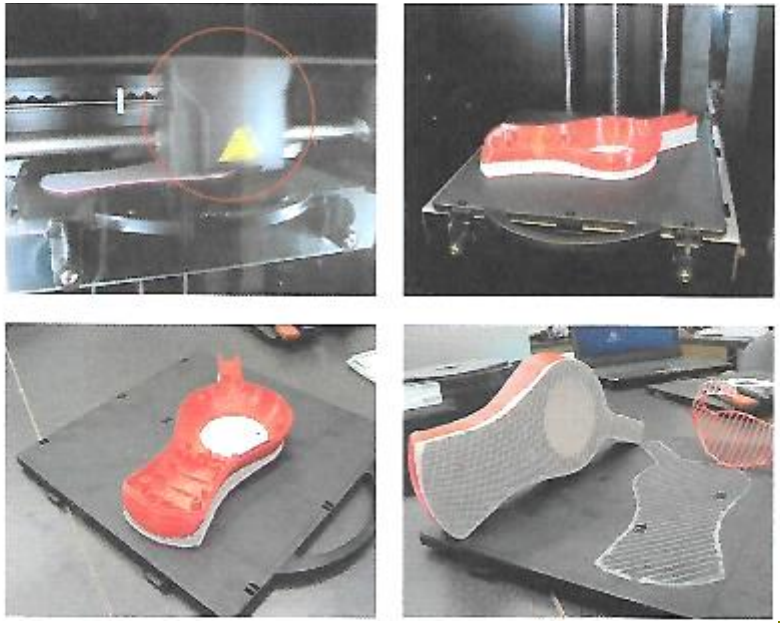
Liquid-based systems use photopolymers that are cured with an ultraviolet light source. These can produce very fine layer thicknesses that in turn have very good surface quality requiring little or no extra finishing. The heat deflection temperature for some of the materials is quite low and should be considered.

Industrial System – 3D Systems' Stereolithography Apparatus (SLA)

The first additive rapid prototyping technology was the Stereolithography Apparatus (SLA). It was invented in 1986 by South Carolina-based 3D Systems Corporation and commercialized in 1988, along with the STL file format. SLA is characterized by high surface quality and smoothness of the parts.

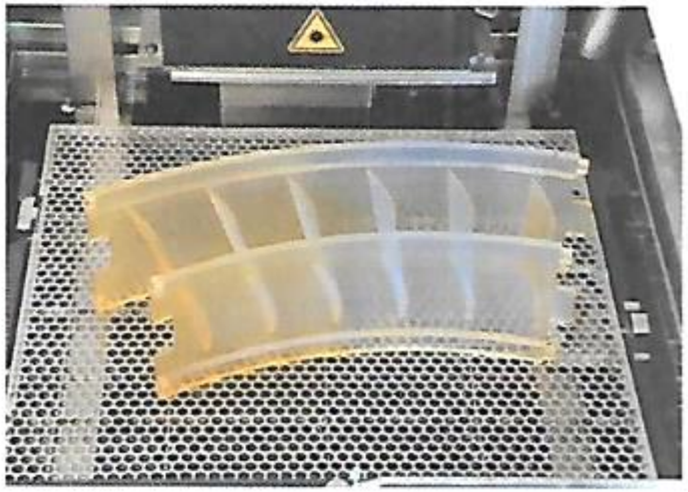
The technology makes use of a UV laser that is directed on to the surface of a vat of photopolymer. The laser traces the slices of the STL (stereolithography) files on to the surface of the liquid, which is then locally cured by the energy from the laser. The hardened section can be lowered and recoated with photopolymer so that the next section can be created. This process continues until the entire part has been created. Support structures are generated during the build to support overhangs and voids within the object. After printing, the support structure is removed. The smooth surface quality and fine feature detail is a function of the fine layer thickness. 3D Systems' Viper™ SLA system, for example, builds at a mere 0.02mm layer thickness, eliminating most staircasing. There is a wide range of materials available for this process that mimic the material properties of some common plastic production materials. The larger industrial systems such as the iPro® 9000 XL SLA system will produce parts as large as 1499 x 762 x 508mm (59 x 30 x 20in).

Extrusion printhead traces the outline of the part (in red) while also building a breakaway support structure (grey).



The part is removed from the platen with a steel scraper and the breakaway support structure is then manually peeled off.

Stereolithography machines from 3D Systems, such as this SLA7000, produce parts from laser-cured photopolymers.

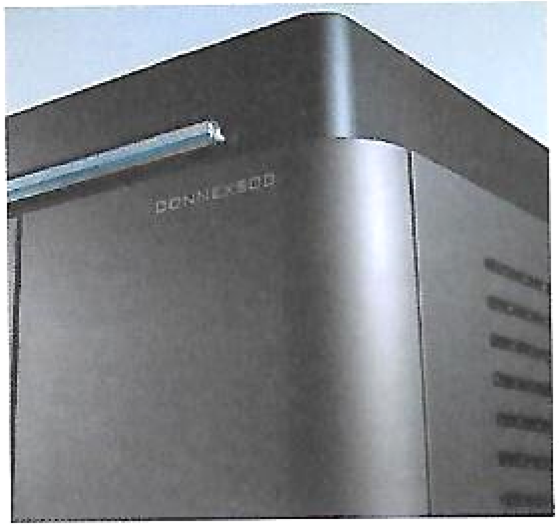


Large, accurate SLAs are commonly used to verify part design prior to tooling production.

Office 3D Printer – Objet Geometries

Objet Geometries produces a series of desktop 3D printing systems using acrylic-based photopolymers that are cured instantly with UV light. These systems also produce very smooth high-quality parts.

Objet's FullCure® Materials range is composed of rigid materials with strength characteristics that simulate ABS as well as polypropylene. There are also rubber-like materials that simulate the properties of thermoplastic elastomers or silicone. The PolyJet™ technology uses dual printheads to print modelling and support material simultaneously. The parts require no post-curing, but the support material has to be washed off. Objet parts are characterized by extremely thin build layers producing high-quality surface parts. The Objet24 and Objet30 printers are the entry-level systems and produce parts in very fine build layers of 0.028mm. They are currently limited to printing rigid opaque type materials. The higher-end Eden350V™ printer produces even finer surface quality using layers of 0.016mm, and prints the entire range of materials including optically clear parts. At the very high end, Objet's Connex family of printers uses PolyJet Matrix™ technology, which can print multiple model materials simultaneously to create what the company terms composite Digital Materials™. This also allows the machine to simulate plastic injection moulding of parts with overmoulded elastomeric sections.



The Connex family of 3D printers from Objet Geometries can produce multiple parts, such as the overmoulded elastomeric wheel below.

Summary

Desktop 3D printers have become very good and produce accurate parts that can be used for a variety of prototyping needs. The industrial-type rapid prototyping and desktop 3D printer systems continue to converge in terms of quality of parts and material offerings. The high-end industrial systems will continue to offer larger parts and more throughput, making them a reasonable alternative to injection moulding for many small- to medium-scale production runs.

ADHESIVES AND FILLERS

Safety Check

- Read Chapter 5 on health and safety, pay particular attention to hazardous substances and personal protective equipment
- Read material labels and SDS for glues and fillers
- Water-based products are usually safer alternatives
- Students should be aware of their school policy about materials

Glues

Modelmaking makes ample use of gluing as a form of assembly, as it is quicker and easier than most types of mechanical assembly. Gluing is also the basis for the additive modelling approach, where forms are assembled from their basic elements. Selecting the proper glue is a function of both application and material.

Typical Modelmaking Glues

Type of Glue	Typical Modelmaking Applications	Approximate Cure Time	Precautions*
Cyanoacrylate (Super Glue)	General modelmaking glue. Dissimilar materials can be joined.	Thin: 1–3 seconds Gap filling: 1–2 minutes	Bonds skin instantly; eye irritant: wear eye protection. Use in well-ventilated area.
Epoxy (two-part)	Where extra glue volume is needed. Dissimilar materials can be joined.	Set time varies from 5 minutes to 12 hours	Eye and skin irritant: wear gloves and eye protection. Use in well-ventilated area.
White Glue (PVA – Polyvinyl Acetate)	Paper, cardboard, polystyrene foam, foamboard, wood.	1 hour	May cause eye irritation, but is generally considered a safer glue.
Spray Glue	For joining sheet materials. Bonds to most materials.	30 seconds	Flammable and under pressure. Eye and skin irritant: wear eye protection. Use in well-ventilated area.
Glue Stick	Glue paper and paper templates on to other materials (non-permanent).	30 seconds	Normally considered a safer glue.
Hot Glue	For cardboard and foamboard mock-ups.	10–20 seconds	Can burn skin. Will melt polystyrene foam.
Rubber Cement	Glue paper and paper templates on to other materials (non-permanent).	10 seconds	Flammable. Eye and possible skin irritant: wear eye protection. Use in well-ventilated area.

* Also read each manufacturer's specific safety and use precautions and instructions as well as SDS.

Cyanoacrylate (super glue) (above) is sold in larger containers in hobby shops. The gap-filling variety tends to be more useful as general-purpose glue, while the thin formula will wick between very tight-fitting parts, creating very smooth joints.

Glue sticks, rubber cement, white paper glue and hot glue (above centre) all work on paper. Spray glues (above right) should be used with extreme caution and in well-ventilated environments.

Epoxy two-part glues are available in many formulations and set times (right). A very strong glue for dissimilar materials but also creates more mess.

Tapes

Tapes are used for a variety of purposes. They are used for masking off areas during painting. They are used to hold parts together temporarily as well as permanently. Tapes are also used as guides for sanding or clay sculpting, as will be shown in Chapters 10 to 20 on materials. Drafting tape is a general-purpose tape for modelmaking that does not peel paper or leave glue residue on models: it is therefore preferable to masking tape. Double-sided tape is used to mount parts together both temporarily and permanently. It is also used for holding down softer materials during CNC machining or to stick sandpaper to sanding templates. There are many different grades of double-sided tape available as well as special-purpose varieties.

Foamboard

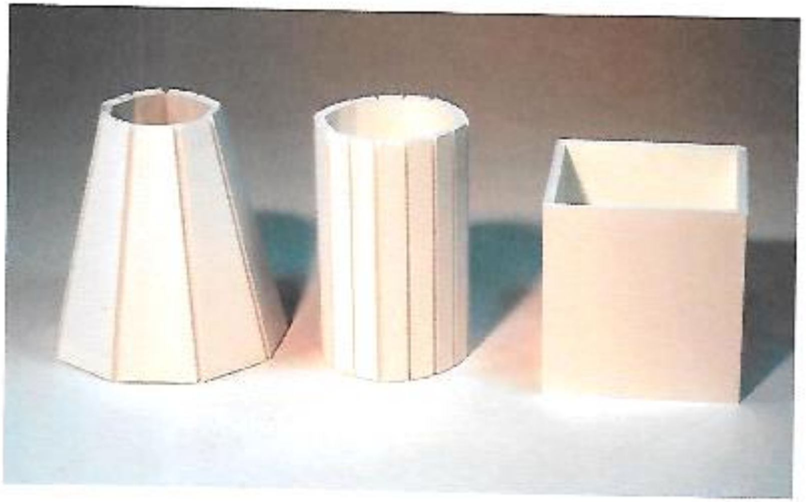
Safety Check

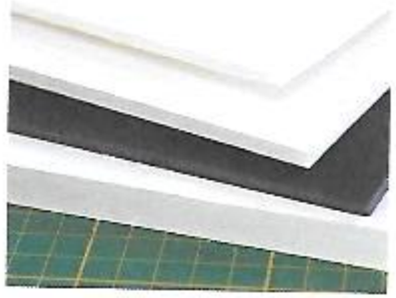
— Read Chapter 5 on health and safety
— Use sharp blades and dispose of in a sharps container
— Use a steel rule as a guide and cut on a cutting mat

Foamboard is a sheet material consisting of a Styrofoam core laminated between two layers of smooth paper, producing a lightweight yet rigid structure. It is available in various thicknesses typically ranging from 3mm to 13mm (⅛in to ½in), with 6mm (3/16in) being the most common choice. It is easier to work with and produces neater and stronger models than corrugated cardboard. This is because the foam centre produces a uniform solid edge that is also easy to cut. The best source for foamboard is the local art shop, which usually carries a range of thicknesses and sizes, but craft and stationery shops also tend to carry a small selection. Different colours are available, but the standard white is mostly used in practice because of its neutral colour.

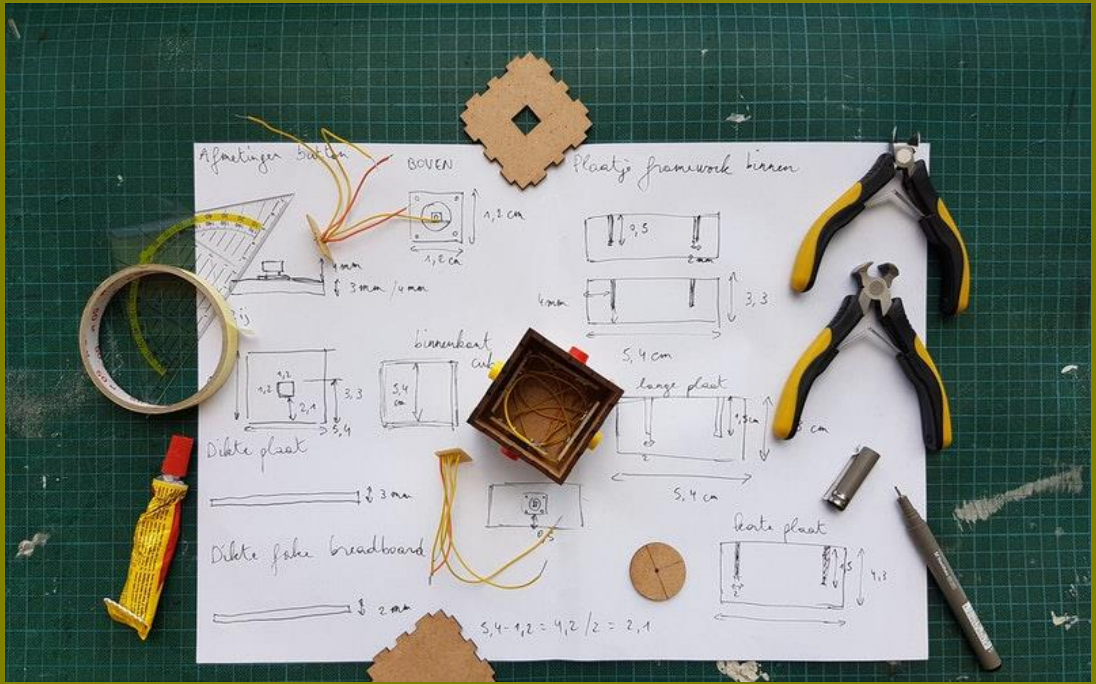
Most geometric shapes can easily be created in foamboard. More advanced organic shapes can also be approximated by a series of cross sections as shown in the previous chapter (see page 89).

Foamboard is used to study both form and function. The product's internal configuration is often prototyped by using real parts such as batteries, motors and other electronics in conjunction with foamboard. This gives the design team a good idea of assembly and fit. The Sonos ZonePlayer 120 is a wireless digital amplifier whose casing was developed by Y Studios in San Francisco. The designers made extensive use of foamboard in the design process, which allowed them to explore functional as well as visual aspects through this low-fidelity material. The assembly sequence was, for example, explored to test the viability of the product design intent. Real speaker connectors were added to study how they interfaced with the back panel and the circuit boards within. Thinner cardboard was used to simulate circuit boards, with polystyrene foam blocks standing in for electronic components. This example shows how low-fidelity materials can be modified rapidly, thus keeping the design process fluid. The designer gets a good feel of the proportions and complexity early in the process before the design progresses into 3D CAD development.





Foamboard is available in various colours and thicknesses.



Prototipe atau *prototype* sering dikenal sebagai permodelan kerja yang paling dasar dari suatu pengembangan program. Dalam berbagai hal, *prototype* digunakan sebagai contoh mula-mula atau purwarupa dari suatu rancangan produk. Hal ini juga dikenal dalam dunia teknologi dan rekayasa perangkat lunak hingga industri manufaktur dan sebagainya.

Secara etimologis dan historis, Merriam Webster Dictionary menyebut kata *prototype* pertama kali digunakan pada tahun 1552 di Prancis dan berasal dari bahasa Yunani *prototypon*. Kata ini dapat diartikan sebagai sebuah model orisinil dari sesuatu yang sedang dipolakan atau dikembangkan.

Di sisi lain, kata *prototype* adalah masa Medieval Latin dengan penggunaan *prototypus* sebagai bentuk orisinil atau primitif dari sesuatu. Kata ini berasal dari dua kata bahasa Yunani, *protos* dan *typos*. *Protos* sendiri berarti “yang pertama” sedangkan *typos* dapat diartikan sebagai pola atau impresi.

Keuntungan *Prototype*	**Kerugian *Prototype***
Adanya *prototype* memunculkan skema komunikasi antara klien dan produsen	Klien dapat serta-merta melakukan kritik maupun meminta pengembangan yang terlampau jauh dari acuan para pengembang terkait kualitas produk atau klien terlalu banyak ikut campur
Pengembangan produk atau sistem yang akan lebih efisien dan hemat waktu	Memungkinkan adanya potensi konflik atau friksi antara kemauan klien terhadap pengembang dengan mengacu pada *prototype* yang sudah ada
Klien dapat berkontribusi aktif dalam proses pengembangan produk melalui acuan *prototype* yang sudah dipresentasikan	Pengembang terlalu terpaku pada *prototype* sehingga memungkinkan adanya kondisi lalai terhadap proses pengembangan kualitas atau bisa menganggap *prototype* sebagai produk jadi
Penerapan keinginan klien dan pengembang/produsen dapat lebih mudah diimplementasikan dalam capaian produk (demonstrasi *prototype* produk)	Cukup memakan banyak biaya karena diperlukan budget yang cukup besar untuk membuat *prototype* di awal proyek

Dalam dunia industri maupun teknologi informasi, *prototype* adalah purwarupa dari suatu pemodelan produk. Hal ini digunakan untuk beberapa kepentingan usaha, khususnya dalam urusan pengembangan produk atau pesanan klien tertentu, baik secara fisik maupun digital.

Menurut Techopedia, *prototype* dalam dunia teknologi didefinisikan sebagai model asli, bentuk atau contoh yang berfungsi sebagai dasar untuk proses selanjutnya. Dalam teknologi perangkat lunak, istilah *prototype* adalah contoh kerja di mana model baru atau versi baru dari produk dapat diturunkan atau dikembangkan.

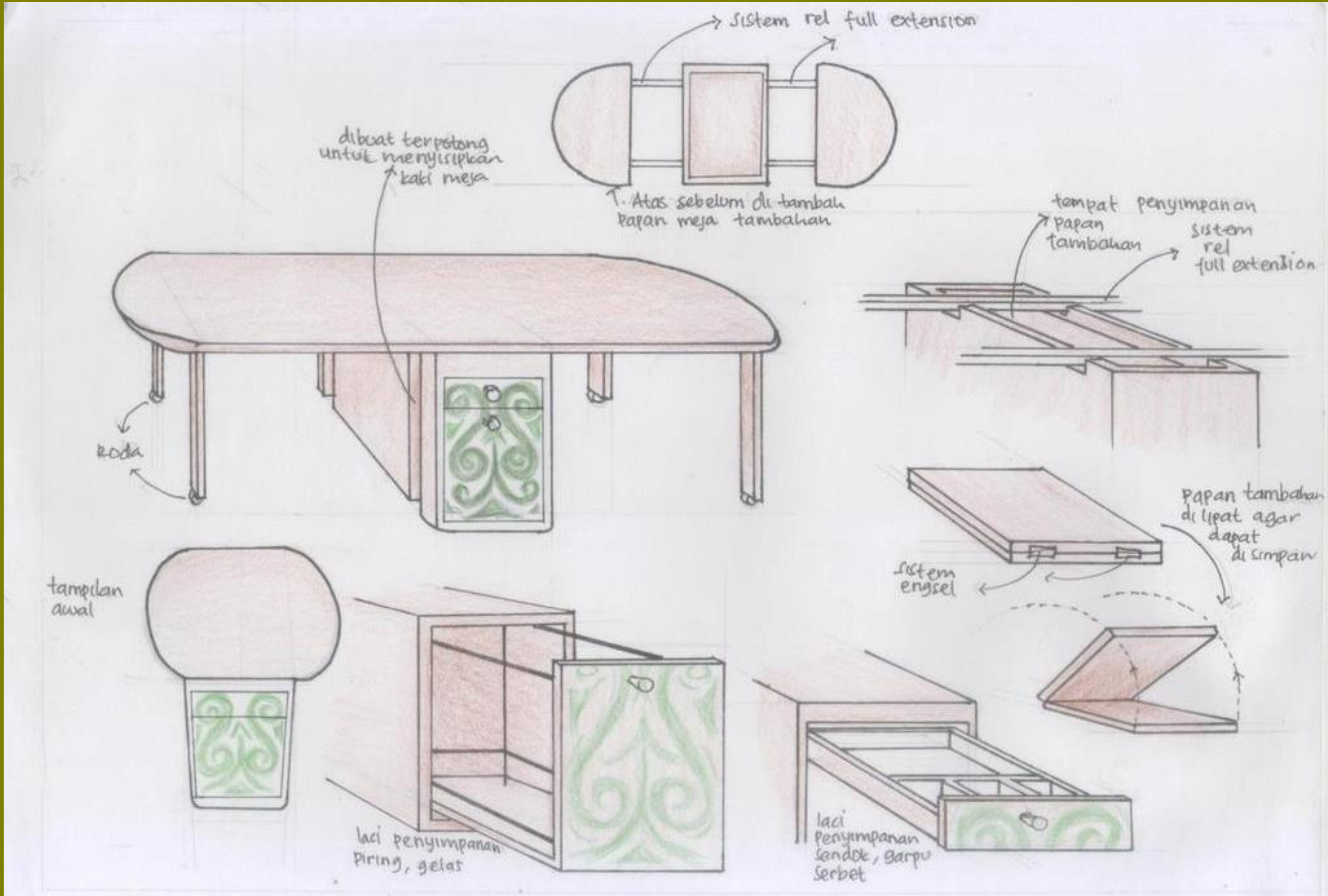
Bagi pengembang atau developer, pembuatan *prototype* dapat bertujuan untuk memudahkan proses penjelasan rencana produk dengan cara demonstrasi fungsional. Tujuan utama ini dilakukan agar klien dan pengembang memiliki satu pandangan yang cukup atas rencana produksi.

Selain itu, *prototype* juga dapat bertujuan untuk mempermudah klien jika hendak melakukan modifikasi terhadap hasil akhir produk yang dipesan. Secara umum, *prototype* bertujuan untuk memberikan spesifikasi sistem kerja yang tidak hanya bersifat teoretis, tetapi juga praktik nyata. Proses pembuatan *prototype* menjadi suatu langkah formalisasi dan dapat berfungsi sebagai evaluasi ide.

Dilansir Uxpin, *prototype* atau *prototyping* bertujuan untuk menyelesaikan masalah terkait kegunaan atau fungsional sebelum suatu produk diluncurkan. Hal ini berarti pula mencakup proses pembenahan area yang perlu diperbaiki hingga kemudian dikembangkan sampai menjadi produk akhir.

Memudahkan presentasi produk

Hampir di tiap pameran produk atau semacamnya, peran *prototype* menjadi amat penting. Sebabnya, adanya *prototype* dapat memudahkan pengembang untuk mempresentasikan ide dan konsepnya kepada calon konsumen atau bahkan investor. Hal ini tentu saja akan sulit dipahami jika pengembang hanya merepresentasikan konsep dan teorinya saja tanpa ada *prototype* fisik pada orang lain.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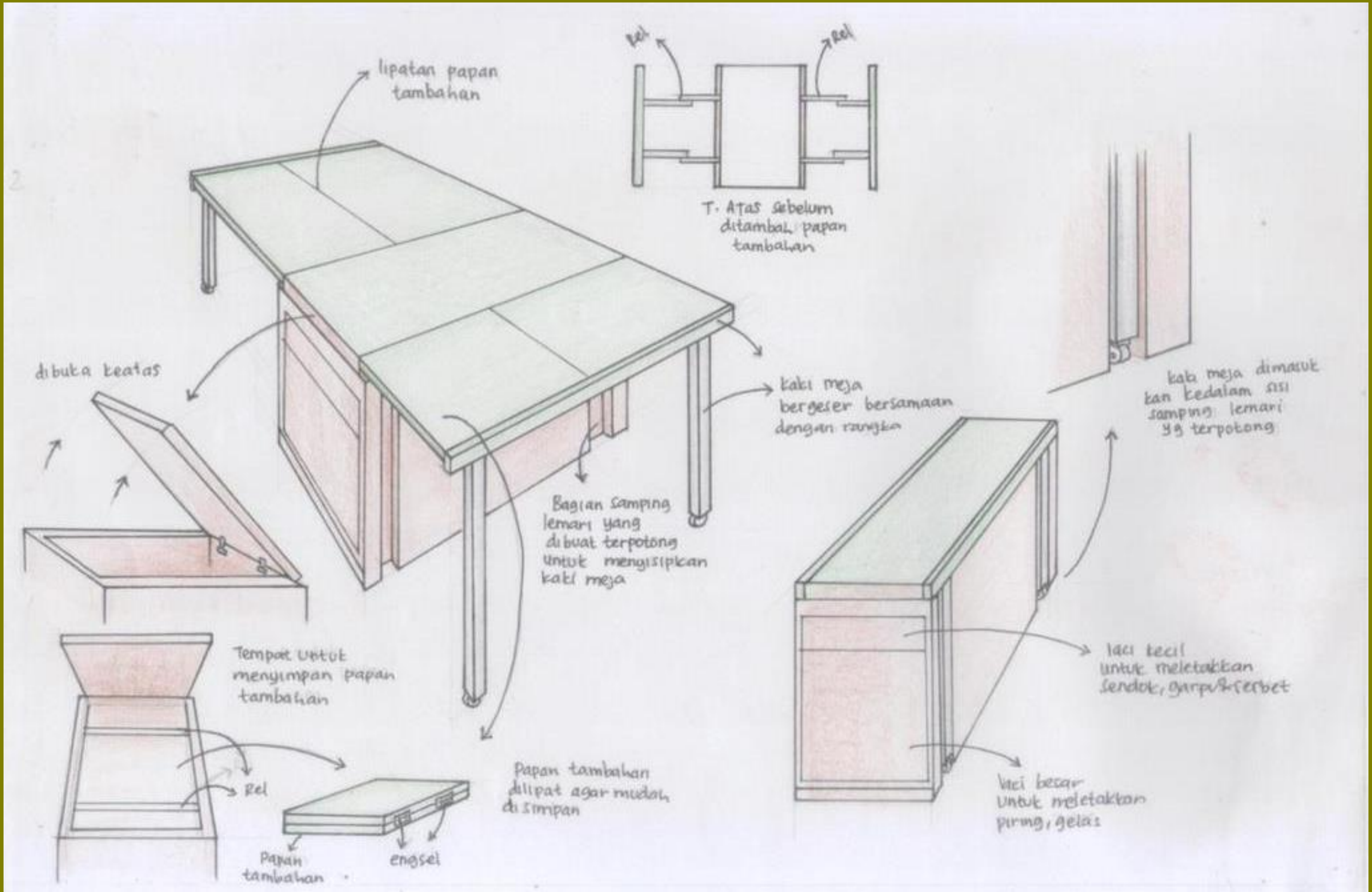
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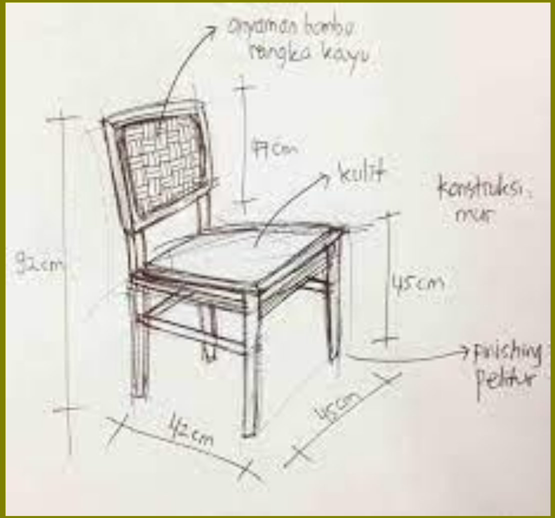

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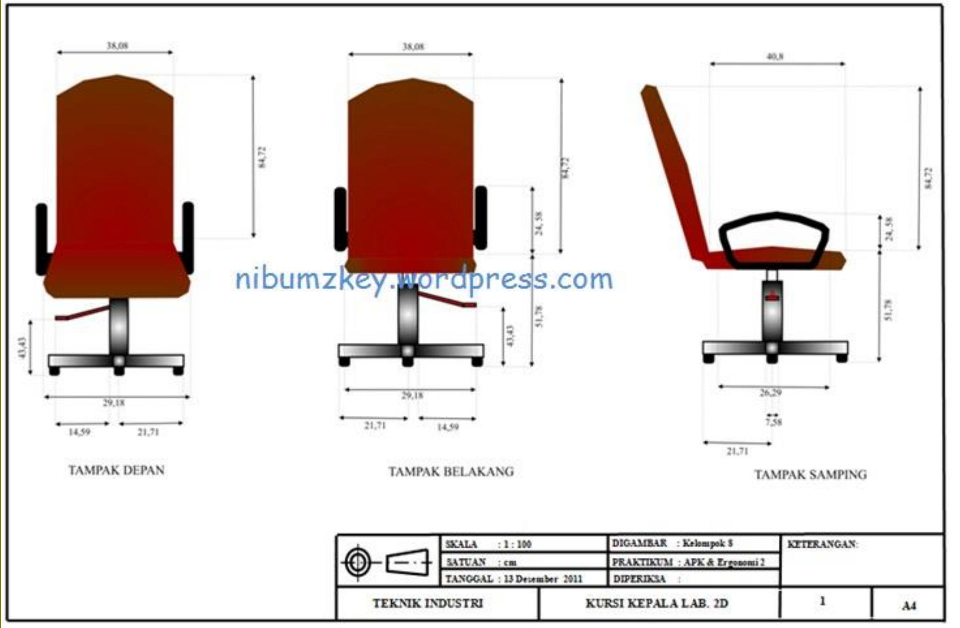

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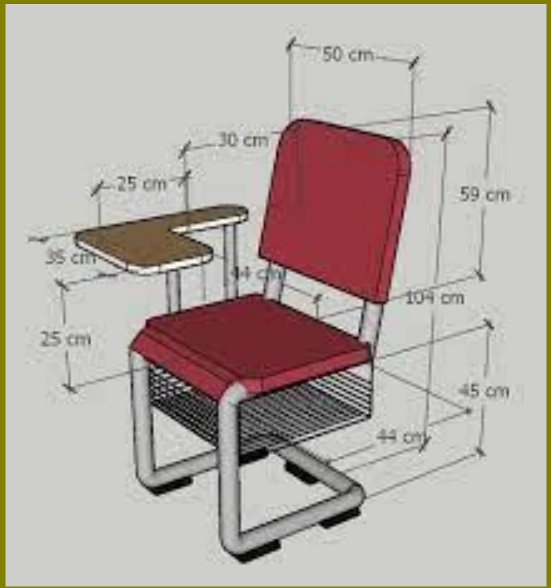

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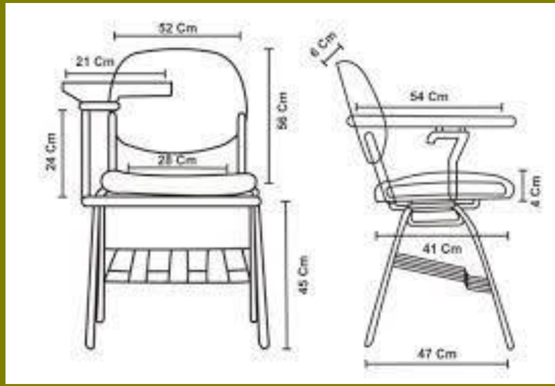

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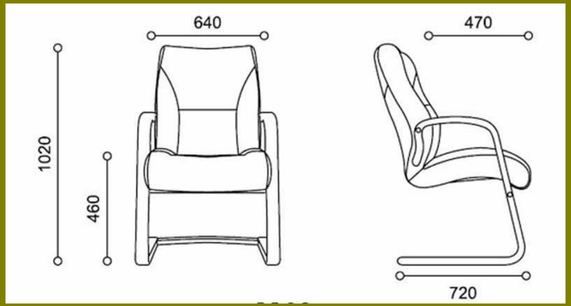

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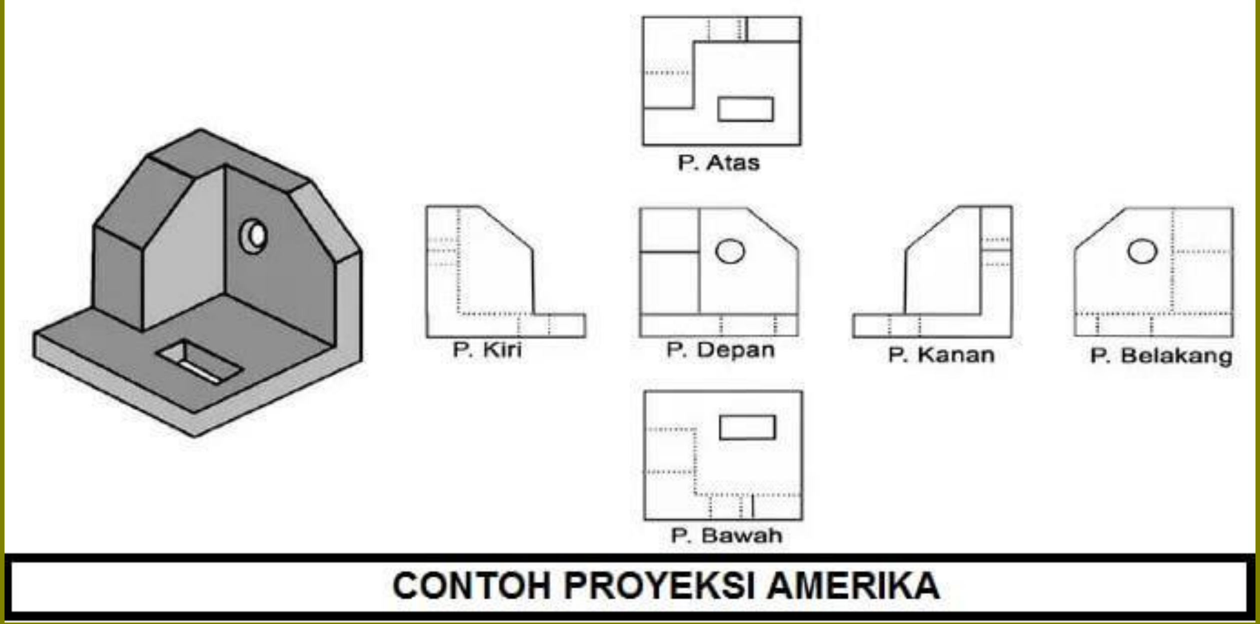

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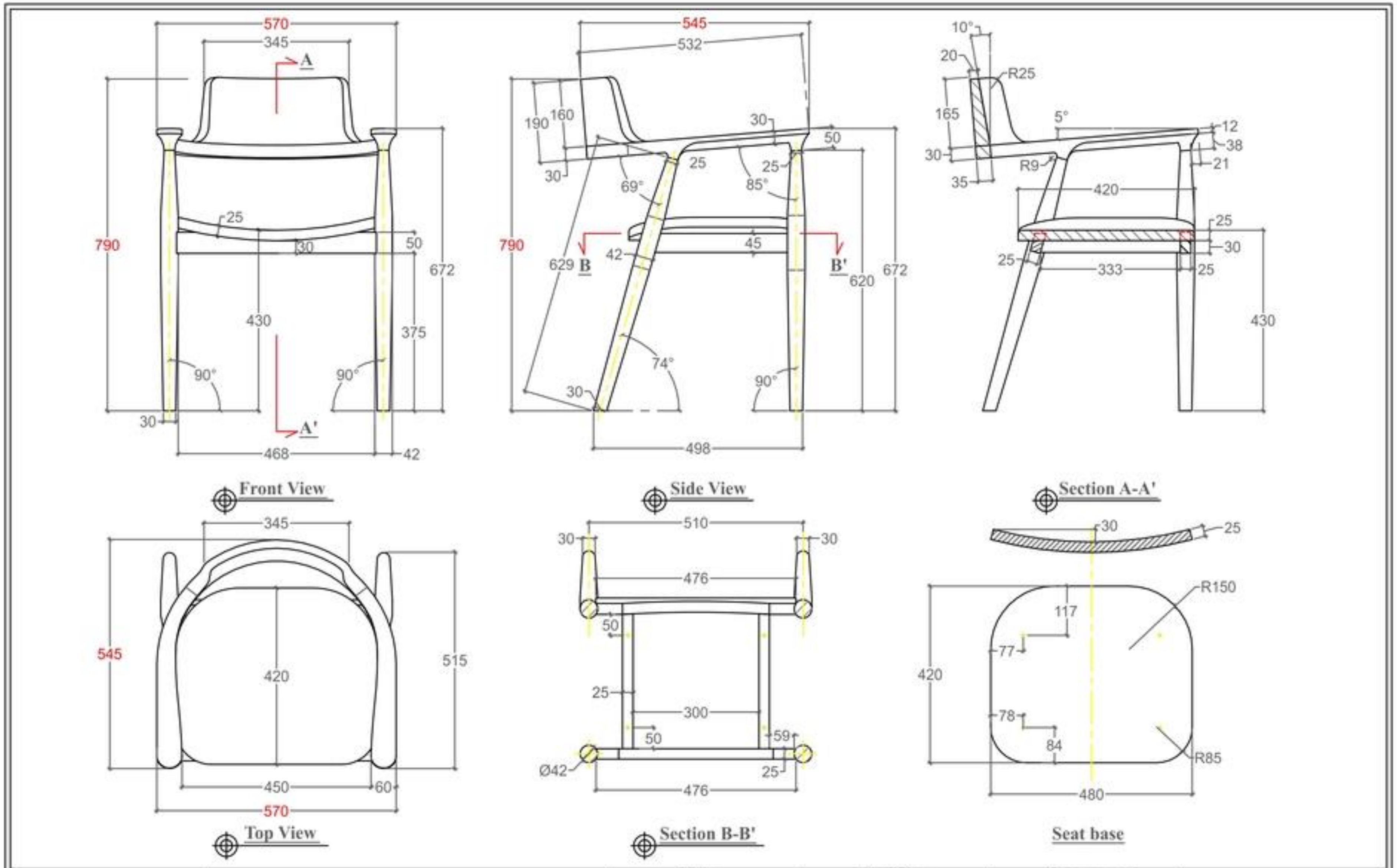

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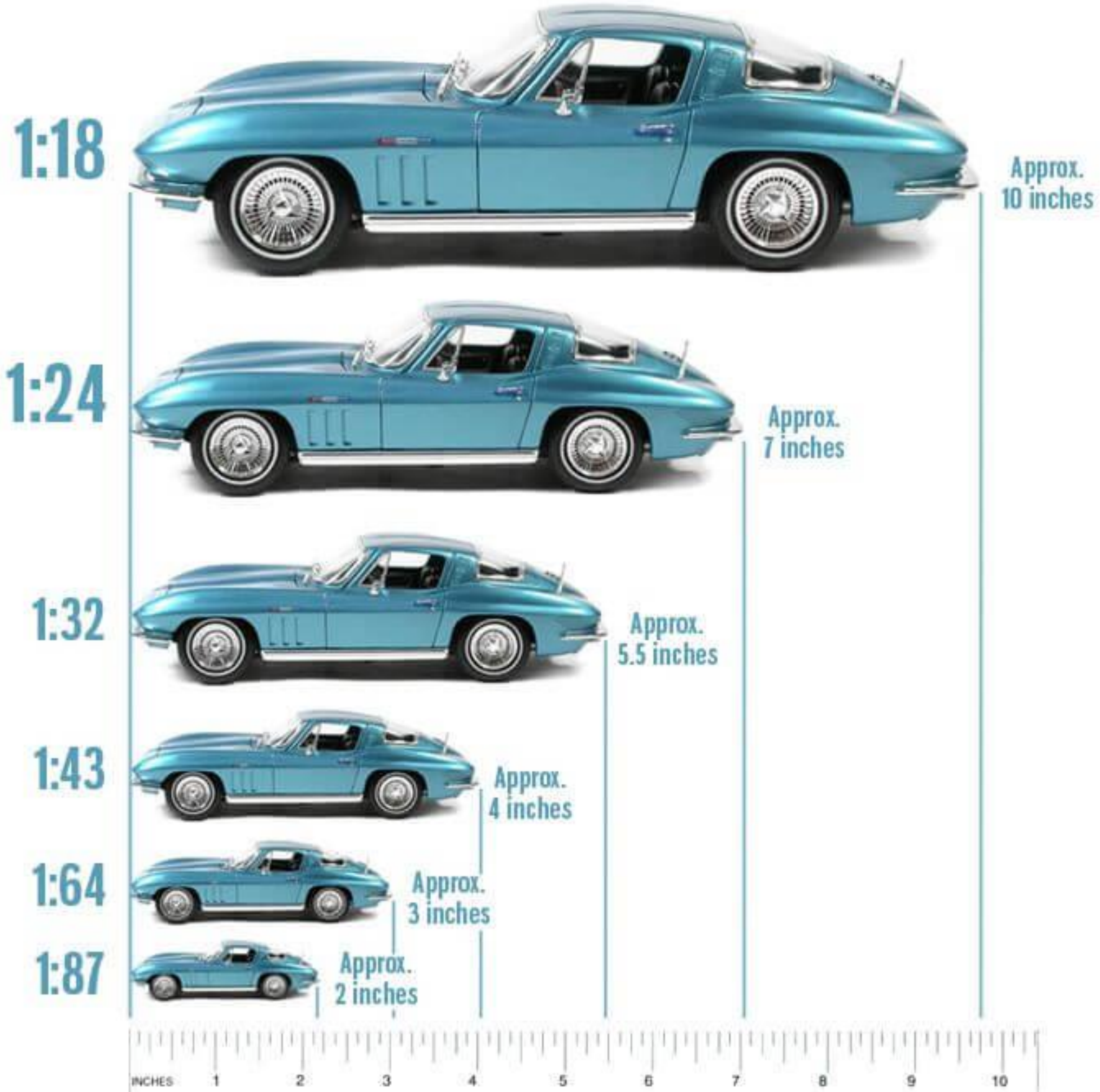

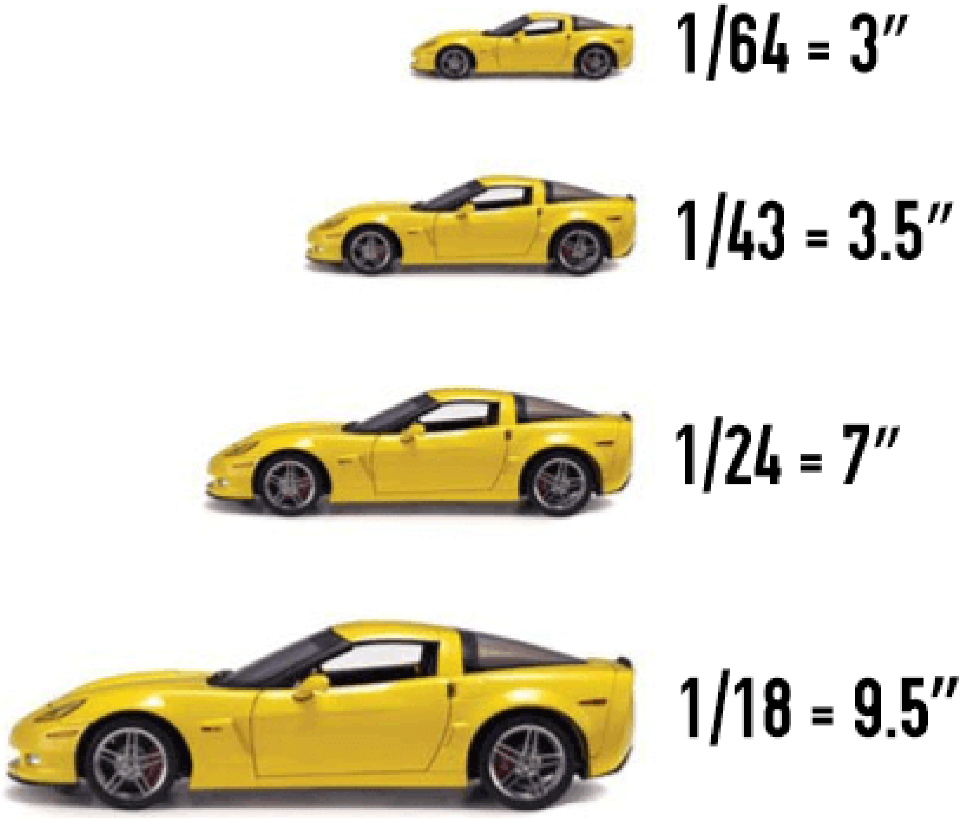

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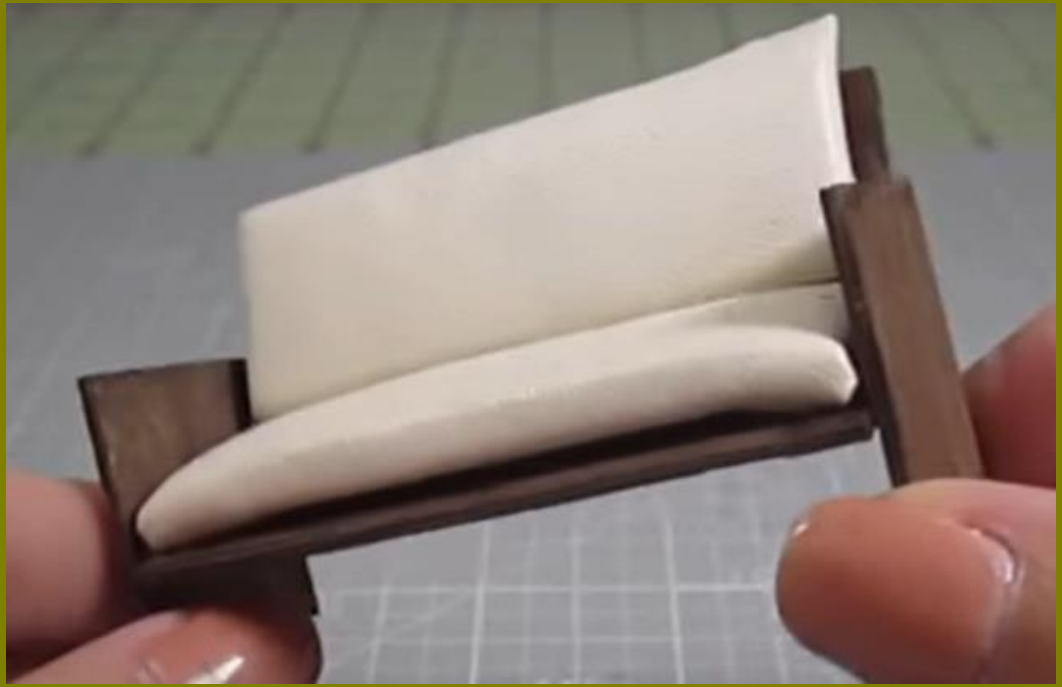

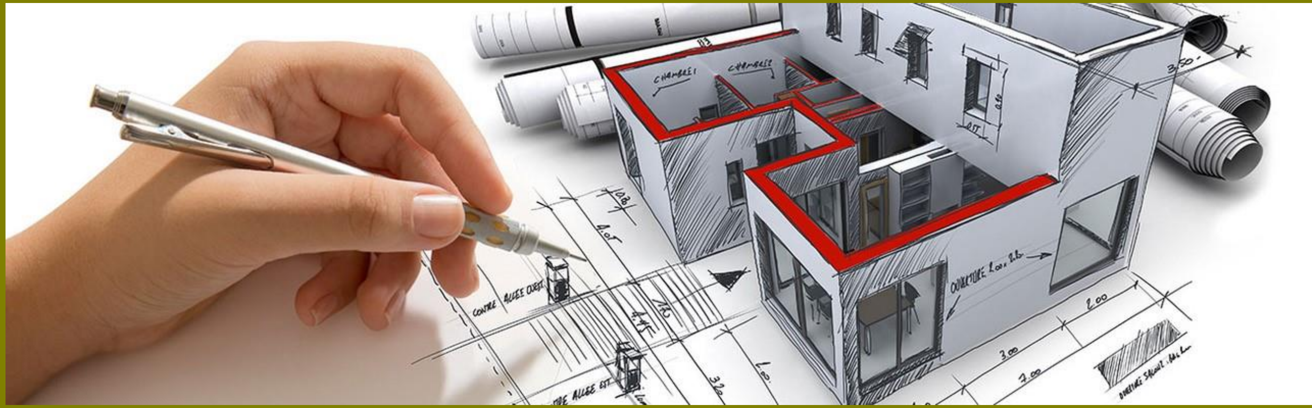

$$\text{Skala} = \frac{\text{panjang miniatur pesawat}}{\text{panjang sebenarnya pesawat}} = \frac{13\text{ cm}}{65\text{ m}} = \frac{13\text{ cm}}{6.500\text{ cm}} = \frac{1}{500}$$

1. Skala pembesaran : digunakan jika gambar yang dibuat lebih besar dari benda sebenarnya
2. Skala penuh : digunakan jika gambar pada kertas dengan benda sebenarnya itu memiliki ukuran yang sama.
3. Skala pengecilan : digunakan jika gambar asli lebih besar dari pada gambar

Sekian

td 01-2021