klöckner pentaplast

white paper

COMPARATIVE ANALYSIS OF POLYMER ROLL-FED SHRINK-LABEL SUBSTRATES

The purpose of this paper is to review the various polymers currently available in the market for roll-fed shrink-label substrates. There have been recent developments in new polymer substrate offerings and this paper will discuss key performance attributes for roll-fed shrink-label applications. The discussion will list available substrates; provide relevant information regarding printing, shrinkage, and physical properties; and review equipment technology, seaming techniques, and material cost versus value. Polymers are PVC roll sleeve, PETG roll sleeve, OPS, OPP, and polyolefin. Actual selection decisions or overall recommendations are beyond the scope of this paper.

AVAILABLE SUBSTRATES FOR ROLL-FED SHRINK LABELS

PVC: Polyvinyl Chloride (clear, transparent, opaque)

PETG: Polyethylene Terephthalate Glycol-modified (clear and opaque)

OPS: Oriented Polystyrene (clear and opaque)

OPP: Oriented Polypropylene (clear and opaque)

Polyolefin: Various (clear)

BACKGROUND INFORMATION

Market trends for roll-fed shrink-label substrates

There have been a number of developments driving demand for roll-fed shrink-label substrates. Intense competition for retail shelf space and corporate mandates of strong unit sales growth have led to retail marketing strategies that maximize packaging design to help achieve these goals. Eyetracking research[1] has shown that colors and shapes play a significant role in influencing buyers' selection. Shoppers are drawn, in sequential order of influence, to colors, shapes, numbers, and, finally, words.

Traditional shrink sleeves, also known as transverse-direction oriented (TDO) sleeves, have been an excellent method of integrating brand messaging in ways that allow packaging designs to maximize colors and shapes. Designers can incorporate unusual eye catching container shapes and colors and distortion print vivid graphics on a shrink film and merge the shape and graphics together through the shrink process. The result is a 360 degree message board for the brand along with a captivating visually attractive package. Through new technologies, roll-fed shrink films are being increasingly adopted as a shrink-sleeve material.

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Technology trends for roll-fed shrink-label substrates

Advances in new labeling technology have been driving a growing trend in roll-fed shrink-film development over the past several years. Major labeling equipment companies, such as Krones, Sacmi and Trine, have developed roll-fed lines that incorporate solvent seaming in the trailing edge overlap seam, which incorporate roll-fed shrink labels that achieve high-shrink percentages while maintaining the integrity of the seam throughout the labeling process. Krones and Trine can also help brand owners retrofit existing roll-fed labeling lines to use roll-fed shrink sleeves.

Sidel has independently developed glueless labeling equipment that requires roll-fed shrink technology. Sidel equipment utilizes a heat bar to weld the label overlap. This process allows the use of high shrinkage roll-fed shrink films due to the resultant strength of the welded seams.

SHRINK REQUIREMENTS DRIVE MATERIAL SELECTION

Higher levels of shrink deliver greater design freedom

The key to achieving design freedom is to create a container with an eye catching shape and meld it together with a label consisting of colorful graphic brand images and strong messaging effects. The higher the level of shrink offered, the greater the design freedom available to the packaging designer. As roll-fed shrink-label substrates have evolved, a greater level of design freedom is being delivered in terms of higher levels of material shrinkage. This enables the designer to vary the shape of the container and simultaneously provide a label that conforms to the container shape. The goal is to use this type of label to capture consumer attention so that the product is noticed and ultimately purchased.

In the early stages of roll-fed shrink-film label substrate development, the available shrink percentage was limited. OPP films (oriented polypropylene) have typically offered shrinkage properties of 10-15%, although some are said to offer shrinkage levels in the 20% range. These products offered some design capability allowing the label to conform to small changes in container shape.

For many applications, OPP continues to be an excellent substrate. However, the need in the market for labels that can conform to more dramatic shapes continues to grow. To meet this need, there has been a corresponding development in roll-fed shrink label equipment and in new roll-fed shrink substrates that can deliver the higher levels of required shrinkage. In addition to providing a comparison of shrinkages that various substrates deliver, other physical and performance properties will be reviewed and evaluated.

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Table 1. Labeling Technology

Technology	*Seaming Method*	*Shrinkage Range*				*Meets Maximum Shrink Capability*
Labeler Manufacturer		I	II	III	IV	***Polymer***
		0-20%	*0-40%*	*0-60%*	*0->60%*	
Accraply Trine, Krones	Standard Hot Melt	•				PVC, PETG, OPS, OPP, polyolefin
PE Labeler	Self Adhesive	•				PVC, PETG, OPS, OPP, polyolefin
Krones	UV Hot Melt	•	•			PVC, PETG, OPS, polyolefin
Sacmi	Solvent	•	•	•	•	PVC, PETG, OPS, polyolefin
Sidel	Thermal	•	•	•	•	PVC, PETG, OPS
Accraply Trine, Krones	Solvent	•	•	•	•	PVC, PETG, OPS

Table 1 shows these new emerging technologies and the levels of shrink each technology can offer. As can be seen in Table 1, there are a number of equipment manufacturers now engaged in producing labelers that require roll-fed shrink films. These machines have varying seaming technologies, and each seaming technology offers a different shrinkage capability.

For example, in the case of seaming with hot-melt adhesives, machine direction (MD) shrinkage is limited to a range of 20% due to the application temperatures required to apply the adhesive. More aggressive adhesive formulations require higher heats, which can distort the shrink label and label seam. All substrate materials can be seamed with hot-melt adhesives in this 20% shrink range. UV hot-melt adhesive seaming, a technology offered by Krones, can offer 40% or greater MD shrinkage. OPP films cannot offer this higher level of shrinkage. Heat bar and solvent seaming can maintain the seam integrity with shrinkage levels at 60% or greater. In a steam shrink tunnel, some polyolefins as well as PVC roll sleeve and PETG roll sleeve can deliver higher levels of shrinkage. Most polyolefins reach ultimate shrinkage of about 50% at 95°C while OPS can shrink to 60%.

So when deciding on the correct material to specify, it is important to take into consideration the labeler and seaming method being used in order to determine the best polymer for the application.

PRINTING CONSIDERATIONS

PVC roll sleeve is generally considered to be one of the most versatile plastic substrates in terms of ink receptivity, ease of gluing, and static properties. OPS, OPP, and polyolefin are often considered given their yield advantages (more area per unit for printing). Printing on PETG roll sleeve, OPS, polyolefin, and OPP require slightly different printing techniques compared with PVC roll sleeve and, sometimes, benefit from specially made primers.

Typical fountain ink formulations are comprised of 65% water or solvent in a mix of pigments, resins, and modifying additives. Water-based inks require alteration of the surface energy of the film to promote bonding. As a rule of thumb, the difference in surface energy of the ink and the film should be 10-12 dynes/cm. Since most of these inks have surface energies in the 40 dyne range, most films would need to be treated to enhance the dyne level to greater than 50. Care must be taken when treating low dyne level materials such as OPS and OPP to higher surface energies (see Table 5). Overtreatment can result in oxidation of the film surface, resulting in poor ink adhesion.

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Solvent-based inks generally do not require surface enhancement. Most are comprised of an 80/20% ratio of alcohol to acetate. This blend will change based on the polymer substrate, as, for example, the acetate content in OPS inks would be reduced to 10% or lower as acetates, hydrocarbons, and ketones could attack the polymer bonds and soften or swell the film. All substrates are susceptible to plasticization depending on the solvent used, which could result in an antiplasticization effect causing brittleness and potential web breaks in the printing or label application processes. Drying conditions and the effectiveness of drying are major factors in minimizing solvent retention and/or blocking.

Radiation-cured inks are 100% solids and utilize cationic or free-radical mechanisms in the presence of UV light to complete curing. Curing is completed in cationic mechanisms after an initial exposure to UV light where the reaction of the photoinitiator, as in an epoxy based adhesive, and UV creates a catalyst that actually completes the cure. Free radicals, as in acrylic based chemistry, require constant UV exposure. Transmission of UV light through the film is an important consideration with this type. Long-time exposure to short wave UV (UVB, UVC) light can break bonds in some polymers such as PVC roll sleeve and cause chromophores – color development due to the resultant carbon-carbon double bond formation. PETG roll sleeve absorbs UVB and UVC so minimal curing would occur. Either can be successfully cured with UVA and a corresponding adhesive system designed to cure in this wave length. Polyolefin and OPP will transmit UVB at 70 and 60%, respectively. OPS will transmit about 45%.

Selection of the proper ink for printing these polymers also depends on the method of printing application. Typical printing types are flexo, gravure, and rotary offset, as well as a growing volume of digital printing equipment. All of these polymer substrates require special coatings to augment digital ink receptivity. Given the variety of commercially available equipment and ink systems, it is recommended that the printer work together with the ink and substrate suppliers to determine and select the optimal ink package suited for the given substrate. These vendors may suggest a solution that requires no surface treatment or may suggest a surface treatment or offer a primer that is well suited for ink adherence to the substrate. Table 2 summarizes basic printing methods by polymer. The red dots illustrate that polymer surface modification is required to improve printability or that special care is needed to print the material. As discussed, PETG roll sleeve can be successfully printed with UV inks, but the curing wavelength is limited to UVA or to catalyst based ink systems.

Table 2. Printing Performance

Printing Performance	PVC	PETG	Polyolefin	OPS	OPP
Printing Ink/Application					
Solvent Gravure	•	•	•	•	
Waterbased Gravure	• (red)	•	• (red)	• (red)	• (red)
Solvent Flexo	•	•	•	•	
Waterbased Flexo	• (red)	•	• (red)	• (red)	• (red)
UV Flexo	•	• (red)	•	•	• (red)
Offset Litho	•	•	•	•	• (red)
Digital	• (red)	• (red)	• (red)	• (red)	• (red)

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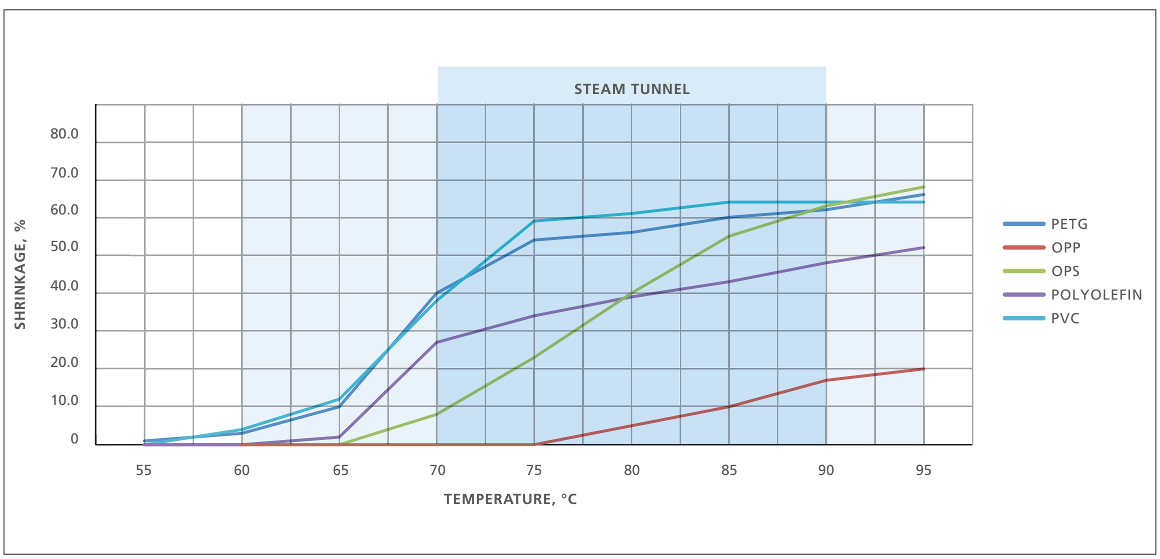
POLYMER SHRINK CURVES

Chart 1 shows the shrink curves for the polymer substrates plotted by shrink percentage at a given temperature. The curves in this chart are representative of the movement or shrinkage that the material would exhibit in a steam tunnel. Not only can shrink initiation and ultimate shrinkage be obtained from a shrink curve, predictive shrink performance and the quality of shrinkage with respect to possible defects in the finished label can be understood.

For example, rapid shrinkage (greater than 40% over a 10° temperature range within 10-20° of shrink initiation) can lead to wrinkles. Fast shrinking films with low shrink force can also cause wrinkles to develop. These films will stop shrinking at the moment of contact with the container and could show localized areas with poor shrinkage commonly referred to as "fisheyes." Low shrink force films can cause problems with incomplete shrinkage at high-shrink positions on a container such as narrow necks. Films with insufficient shrinkage can show wrinkles or air pockets (non adherence to the container shape). There must also be some consideration given to opposite axis orientation. Excessive shrinkage or growth in this axis can cause non-uniform label lines at the bottom or top of the container known as "smileys." Optimization of the steam tunnel zones and rod positions can prevent many of these issues.

Chart 1. Polymer shrink curves



Note: Blue shaded area indicates typical steam tunnel operating temperatures

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As exhibited in Table 3, PVC roll sleeve and PETG roll sleeve are optimal for steam tunnel applications due to fast shrinking and high ultimate shrinkage at 95° C, also as exhibited in the shrink curve shown in Chart 1. Steam shrinkage is the best solution for low-temperature shrink films owing to the low temperature gradient between points within the tunnel and offers high heat capacity. In contrast, IR and hot-air tunnels operate at very high temperatures with low heat capacity and a much higher temperature difference between points within. These tunnels are better suited for slow shrinking films with low ultimate shrinkage.

However, most polymers shrink effectively with hot air and IR equipment with the exception of OPP. OPP requires a significantly higher temperature to effect shrinkage and the MD shrinkage is usually well below 20%. PVC and PETG roll-sleeve films perform well for all tunnel types. Polyolefin and OPS will shrink in a steam tunnel, but, due to slow shrink rates, higher steam temperatures are required. High natural shrinkage of OPS films in storage is also a major concern for use of this substrate in shrink label applications. The red dots in the Table 3 indicate that special adjustments or other requirements may be needed for the particular shrink method and substrate.

Table 3. Shrink tunnel performance

Shrink Method	PVC	PETG	Polyolefin	OPS	OPP
Steam	•	•	• (red)	• (red)	• (red)
Hot Air	•	•	•	•	• (red)
IR	•	•	•	•	• (red)

SEAMING PERFORMANCE

As shown in Table 4, different materials vary in seaming performance and versatility from very good, as demonstrated by OPS, to more limited, as for OPP. PETG roll sleeve and PVC roll sleeve are marginal for use in current hot-melt technologies, offering acceptable seam strength at shrinkages of 20% or less, but the seam quality can be somewhat poor by comparison. Chemical structure of the polymer will aid in determining the correct or appropriate solvent blends required to seam each substrate. Evaporation rate and bonding strength of the solvent are key factors for seaming these substrates. Typical solvent blends can incorporate aromatic ketones with fast evaporation rates blended with alcohol to aid drying. Aliphatic hydrocarbons can also be used to slow the evaporation rate. As previously stated, OPS is incompatible with high acetate concentrations, ketones, and other solvents. Polyolefin is a more difficult material to solvent seam and is not typically a good candidate for most solvents, but advancements have been made in the past few years and solvents are now available. Because it is incompatible with aliphatic, aromatic, and halogenated hydrocarbons, solvent seaming OPP will be extremely difficult.

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Table 4. Seaming performance

Seaming Performance	PVC	PETG	Polyolefin	OPS	OPP
Printing Ink/Application					
Solvent Bonding	•	•	• (red)	• (red)	
Thermal Welding	•	•	•	•	• (red)
Laser Welding	•	•	•	•	• (red)
UV Adhesive Bonding	•	• (red)	•	•	•
Hot Melt Adhesive Bonding	• (red)	• (red)	•	•	•

Thermal bonding occurs with temperature, pressure, and time, and will vary for each substrate to heat seal one layer of the material to another layer of the same material. Higher heat-sealing temperatures are required for polyolefin and OPS. OPP requires a sealant layer for thermal and laser welding. PETG roll sleeve performs poorly using UVB adhesive technology currently on the market.

The red dots in Table 4 indicate that the polymer can be seamed with the given system or technology, but special application or procedure may be required.

PHYSICAL PROPERTIES – TECHNICAL PERFORMANCE

Table 5. Technical performance/physical properties

Technical Performance	PVC	PETG	Polyolefin	OPS	OPP
Physical Properties					
Density*	1.33	1.26	0.97	1.05	0.91
Tensile Strength, kpsi	17.4	15.2	7.3	9.2	18.9
Elongation, %	70	70	83	50	174
Elastic Modulus, kpsi	400	380	340	330	343
Surface Tension, dyne/cm	38	42	38	24	29
Shrinkage (95° C)	65	65	58	25	15
Shrinkage (85° C)	58	58	50	15	5
Shrink Force, psi	350	700	190	286	0
Coefficient of Friction (static)	0.25	0.22	0.21	0.23	0.25
Gloss	130	130	95	135	88
Haze, %	3	1	1	2	1

**Density for PETG is based on PETG roll sleeve produced by Klöckner Pentaplast*

Physical properties by polymer are included in Table 5.

Lower density offers a benefit for higher yields per unit of material. OPP and polyolefin offer the greatest yields while PVC roll sleeve and PETG roll sleeve have the lowest yields per unit within this group of materials. Method of manufacture for these substrates is an additional consideration as average thickness and control can impact the actual yield. Gauge variation can be high in blown and extrusion processes where calendering can lead to variation within only a few microns. Most of these substrates are either blown or extruded, but PVC roll sleeve is typically calendered.

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Oriented films are stressed at high strain rates generally along a single axis such as the machine or transverse directions. This high strain increases the tensile strength of the material in that axis by four to five times its unoriented condition. Substrates with higher tensile strength are tougher and stronger than comparative films and, as a result, can be more difficult to cut. However, orientation along an axis also weakens the material in that direction due to alignment and order of polymer chains, making cutting easier in the axis of orientation. This can facilitate web trimming of roll-fed shrink or TDO films. Cross-direction cutting for either would require sharp blades and tight tolerances if die or compression cutting.

Elastic modulus is indicative of extensibility under load and will have importance for web tensions applied during processing of substrates on, for example, a printing press where tight repeat lengths and registration are required. Generally, higher modulus films will stretch less and exhibit greater stiffness. Although the differences in elastic modulus properties for the substrates observed in Table 5 are small, PVC roll sleeve, PETG roll sleeve, and polyolefin have demonstrated higher stiffness compared to the other substrates. Films with higher natural dyne levels or surface energies can be processed with most ink systems without surface alteration or treatment. Differences can be equated to intermolecular bonding and the electrostatic forces between molecules, but can also result from additives employed to aid substrate manufacture, i.e., lubricants and other modifiers. Based on chemical structure and manufacturing, OPS and OPP have lower values.

For roll-fed shrink films there is a relationship to shrinkage and shrink force. Typically the higher the shrinkage, the higher the shrink force. This can be demonstrated within a polymer group more so than by comparison to other polymers, but generally higher shrink materials also have higher shrink forces. It is important to note that the 85° C shrinkage is characteristic of the performance of these substrates in a steam tunnel at high altitudes. The information in Table 5 displays the shrink limitations of OPP and OPS at 85° and 95° C.

Coefficient-of-friction (COF) is a measure of slip or how one surface moves across another. The importance is in how a substrate moves through and across print stations, conveyor belts, onto the container, or released from a mandrel or loading after processing. Films with coefficient-of-friction values greater than 0.5 are considered non slip. COF is usually specified for a given process and adjusted by the printer with inks or varnishes as needed.

Gloss indicates the level of brilliance and a higher gloss value is considered desirable for aesthetics. All substrates listed have relatively low haze, which is also preferred by converters and brand owners. However, contact clarity offered by materials with higher haze and duller materials also find application in shrink labeling.

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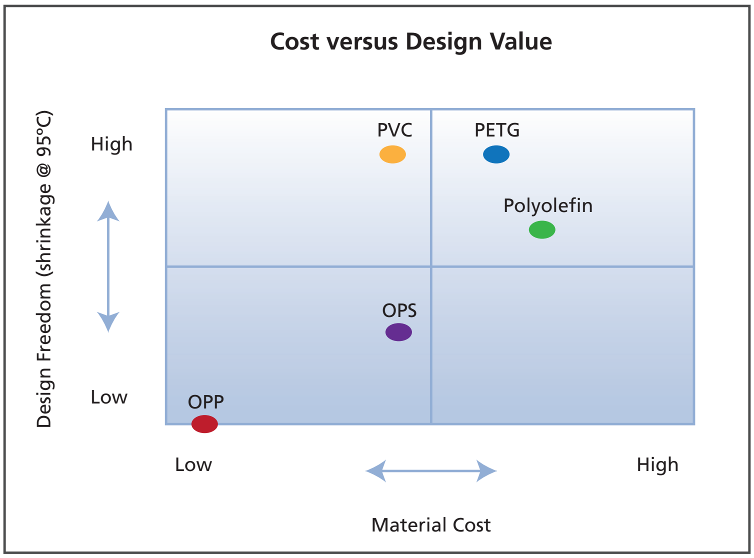
COST VERSUS VALUE OF SUBSTRATE POLYMERS

Cost versus value is another important comparison for material substrates and is shown in Chart 2. Design value is defined by the shrinkage properties of the film at 95° C. The higher the material's shrinkage properties, the greater the designer's ability for label design that will conform to more container shape variation. Material cost shows a relative cost from low to high. PVC roll sleeve has excellent design value relative to cost. OPS and PVC roll sleeve have similar material costs, but a significant difference in shrinkage properties at 95° C. OPP rates low for both cost performance and design value. PETG roll sleeve has a high relative cost, but also delivers high shrink properties. Polyolefin delivers relatively high shrinkage for its design value. It is important to note that this cost model is relevant for 95° C steam tunnel shrinkage and that other models can be used in a similar fashion for other temperatures/shrink methods.

Chart 2. Cost versus design value



Additional consideration can be given to the type of material and the type of label. Even some paper labels, which are considered to be a lower material cost as compared to plastic labels, can have a higher cost per container than the same container with a shrink label. For example, if the cost of a pressure-sensitive label (with multiple labels per container) is compared to a full bodied roll-fed shrink sleeve in any of the applicable polymers (PVC roll sleeve, OPS, PETG roll sleeve, and polyolefin), the sleeve can actually cost less overall than multiple labels. This is especially true if a tamper-evident band is also required. Typically, the PSA label will have full adhesive coverage and a polyester liner that will add to the overall cost difference. The additional application and material cost of a separate tamper-evident band, if used, also increases the cost difference with a multiple psa labeled container in comparison with a roll applied full-body sleeve.

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SUMMARY AND CONCLUSION

Roll-fed shrink films are in the marketplace. These materials have been developed to support a growing trend towards using shrink film now being seamed with new labeling technologies. In order to achieve corporate sales growth targets and to enable their company's products to be noticed and selected by consumers, companies have employed the use of shape and color in their product packaging. Container shape and label technology have enabled the container and label to be merged together to provide eye catching images that get noticed by the consumers.

Some of the materials included in this paper offer higher levels of MD-oriented shrinkage than were previously available. Equipment manufacturers have developed new equipment capabilities that require these roll-fed shrink materials. This includes new glueless labeling systems and also lower cost solvent labeling systems. These new labelers and roll-fed shrink films help provide a higher level of design freedom by offering processes that enable the use of higher shrinking roll-fed shrink films. This, in turn, empowers designers to label an ever wider option of container shapes. PVC and PETG roll-sleeve films offer the highest levels of MD shrinkage at the lowest temperatures.

The important topic of cost versus value was discussed in some detail. Materials were arranged to evaluate both their overall cost and their shrinkage level potential to evaluate overall material value.

All of these polymers offer unique benefits and can be the best choice, depending on the printing, seaming, shrink-tunnel equipment, labeling technology, and shrink requirements. When selecting a substrate, it is recommended that the user discuss the application with the substrate supplier, printer, adhesives supplier, and the labeling equipment manufacturer to help select the appropriate roll-fed shrink-label substrate solution.

Notes:

[1]*Source: Studies by Wharton & INSEAD*

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