*Disclaimer*

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# CHAPTER 3 STRATEGY SELECTION

This chapter discusses key factors to be considered during the strategy selection process for preservation and restoration treatments for jointed plain concrete pavements (JPCP). Treatments for continuous reinforced concrete pavements (CRCP) will be added at a later date. Currently Caltrans does not have a formal selection matrix for preventive maintenance treatments for JPCP pavements. This chapter describes the steps involved in the treatment selection process, including typical methods for assessment of existing pavement condition, determining feasible treatment options, and comparing and selecting treatment options. At present, only specific preventive maintenance treatments are included. In the future, other treatments, such as thin hot mix overlays, will be added.

## 3.1 FACTORS TO CONSIDER

The most important factors to consider during the strategy selection process include ride, skid, and distress type. Noise can also be considered as a factor. Chapters 1 and 2 have provided an extensive discussion on these factors. Another important factor to consider is the durability/longevity of a treatment.

### *3.1.1 Ride*

As indicated, the ride quality is directly related to pavement smoothness which is probably the single most important surface characteristic from the standpoint of the traveling public. A rough pavement not only adversely affects driver safety, fuel efficiency, and vehicle wear and tear but also negatively impacts pavement durability. Therefore, the key factor for improving the ride quality is to improve the pavement smoothness.

### *3.1.2 Skid*

Skid is a measure of the frictional characteristics of a pavement surface. A pavement with a low skid resistance may cause vehicles to slide when the pavement surface is wet. Therefore, maintaining adequate pavement surface friction is important to public traffic safety. The key factor for improving the skid resistance is to improve the pavement surface texture.

### *3.1.3 Noise*

To many motorists, a quieter pavement provides a pleasant driving environment. Considerable studies have been devoted to reducing noise caused by tire-pavement interaction. Current information and findings on quieter pavement can be found at Caltrans website:

http://www.dot.ca.gov/hq/oppd/pavement/qpavement.htm.

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### *3.1.4 Distress Type*

The type of distress on the existing pavement is probably one of the most important factors for the selection of an appropriate strategy. A specific distress may be caused by either a single or multiple mechanisms. The key factor to consider during the strategy selection is to identify treatments that not only mitigate the distress symptoms but also resolve the mechanism that caused the distress. Durability problems, such as D-cracking (although not found in California's rigid pavements) and alkali-silica reactivity (ASR), are primarily material related. Treatment selection for these types of problems would depend on the rate of deterioration.

### *3.1.5 Durability/Longevity*

The durability/longevity of a treatment is another important factor to consider. Caltrans experience has indicated that the estimated lives of joint resealing and cracking sealing may range from 4 to 7 years; diamond grinding may provide estimated lives of 10 to 18 years; dowel bar retrofit have estimated lives of 8 to 15 years; and partial or full depth repairs may last 8 to 10 year or longer. It must be noted that the durability/longevity of the treatment is dependent on the traffic and environmental conditions as well as construction practices.

## 3.2 SELECTION PROCESS

There are three steps currently included in the pavement preservation and restoration treatment selection process for flexible pavements as identified below (Caltrans, 2002; Shatnawi et al, 2006). These processes are also suitable to rigid pavements.

- Assess the existing conditions – These include identification of pavement distresses and assessment of their conditions, as discussed in Chapter 1, and the desired surface characteristics as discussed in Chapter 2.
- Determine the feasible treatment options – The "feasibility" is determined by a treatment's ability to address the functional and structural condition of the pavement while also meeting future needs. Feasibility is not a function of affordability. At this stage of the selection process, the purpose is to determine what treatments might work for a given pavement condition.
- Analyze and compare the feasible options – Once feasible options are identified, they are compared in terms of cost, life expectancy, and extended pavement life resulting from the treatment. At this stage, a life cycle or other cost effectiveness assessment should be made to evaluate the optimum time to apply the treatment to provide maximum cost effectiveness.

Each of these steps is discussed in the following sections.

## 3.3 ASSESS THE EXISTING PAVEMENT CONDITIONS

The first step of the treatment selection process is to perform an evaluation of the existing pavement conditions. This evaluation includes the following processes:

- Review project information from a database and/or available records.
- Conduct visual site inspection of the pavement conditions, as needed.

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- Perform testing on the existing pavement, as conditions require.
- Define the expected performance requirements for the treatment.

### *3.3.1 Project Information Review*

Reviewing project information serves the following purposes:

- Provides the qualitative information needed to determine the causes of pavement deterioration, and to develop appropriate alternatives for repairing the deterioration and preventing its recurrence.
- Provides the quantitative information needed to assess the rate of deterioration of the pavement and the consequences of delaying application of a treatment, to identify feasible maintenance treatments, to make quantity estimates for the selected treatment (e.g., labor, materials, equipment), and to develop input for performing life-cycle cost comparisons of various treatments.

Table 3-1 provides data items typically needed or helpful for various treatment strategies considered in this document.

Table 3-1 Suggested data item needs for treatment strategies for rigid pavements (FHWA, 2001)

| Data Item | Grinding | Load Transfer Restoration | Partial-Depth Repair | Full-Depth Repair |
|---|---|---|---|---|
| Existing Pavement Structure | X | X | X | X |
| Original Construction Data | * | * | * | * |
| Age | * | | * | * |
| Materials Properties | X | | * | * |
| Subgrade | | | | |
| Climate | | | | |
| Distress | X | X | X | X |
| Skid | * | | | |
| Accidents | * | | | |
| NDT | | X | | * |
| Destructive Testing/ Sampling | * | * | X | X |
| Roughness | * | | | |
| Surface Profile | X | | | |
| Drainage | X | | | X |
| Previous Maintenance | * | | * | * |
| Utilities | | | | X |
| Traffic Control Options | X | X | X | X |

**KEY:** X Definitely Needed * Desirable [*blank*] Not Normally Needed

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Possible data sources are:

- Previous design reports.
- Previous construction plans/specifications (new and rehabilitation).
- Materials and soils properties from previous laboratory test programs and/or published reports.
- Past pavement condition surveys, nondestructive testing and/or destructive sampling investigations.
- Maintenance/repair histories.
- Traffic measurements/forecasts for estimating remaining service life.
- Environmental/climate studies or regions.
- Pavement management system reports.

These data may reside in each District office. Caltrans District Materials Engineers should be contacted for this information.

### *3.3.2 Field Distress Survey*

A field distress survey is a very important activity in the process of pavement evaluation and strategy selection. Depending on the size and nature of the project, field distress survey can be conducted through "windshield" observations and/or detailed distress mapping survey involving lane closures. As part of this activity, information on distress type, extent, and severity, pavement roughness, surface friction, and moisture/drainage problems should be gathered (Caltrans, 2000). In addition, requirements for traffic control options for detailed field survey and for construction may be assessed during the field visit. Caltrans Maintenance has been developing forms for flexible pavement surface treatment review checklists and pavement evaluation, as presented in Appendix E. These forms need to be modified to include checklists and pavement evaluation for concrete pavements.

### *3.3.3 Field Sampling and Testing of Existing Pavement*

If necessary, field tests on existing pavements may be conducted. The purpose of the field testing is to verify and/or quantify the extent and severity of the observed distresses. The type of the field testing to be conducted depends on the distresses on the existing pavement. For example, a roughness test may be required if there is concern with surface smoothness or surface texture; a skid test may be needed if there is concern with loss of skid resistance of the pavement surface; a deflection test may be appropriate if there are concerns with pavement structural capacity/integrity, loss of support underneath the PCC slab due to voids, and loss of load transfer capability or efficiency at the joint.

Field sampling/testing may be required to provide additional information for detailed analysis or for laboratory testing if needed. The purposes of field sampling/testing and lab testing are to adequately characterize the structural characteristics of the existing pavement and to develop input for the selection of most appropriate strategies. Depending on the project requirements, field sampling activities may include pavement coring, augering, field testing using Dynamic Cone Penetrometer (DCP), and/or standard penetration test to measure the in-situ strength of the subgrade soils.

When required, laboratory testing may be conducted to verify, confirm, or quantify field observations from distress surveys or from non-destructive test program and to provide additional insight into the mechanism of the distress or to provide additional information needed for the development of treatment strategies. Examples of information that can be determined from laboratory testing include the following:

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- California R-value of an unbound material
- Concrete flexural or tensile strength
- Petrographic testing and analysis for the concrete surface layer
- Resilient modulus of concrete or other materials

The National Highway Institute (NHI) Course No. 131062 (FHWA, 2001) provides an excellent discussion on various field sampling/testing and laboratory testing techniques. It is strongly encouraged that the reader look into this reference when developing a plan for field sampling/testing and lab testing.

### *3.3.4 Performance Requirements*

For rigid pavements, performance requirements vary by the type of treatment applied to the pavement. The treatments currently considered by Caltrans for maintenance include the following:

- Joint resealing and crack sealing. Caltrans makes extensive used of crack or joint sealants in jointed concrete pavements. Asphalt emulsions, fiber and asphalt, rubberized asphalt, and silicone sealants have been used. The estimated lives of these treatments vary from 4 to 7 years depending on where they are applied, existing pavement condition, and traffic levels.
- Diamond grinding. Diamond grinding is used extensively as a maintenance treatment to restore smoothness. Estimated lives of the grinding can be 10-18 years with an average of 14 years depending on the traffic, the environmental conditions, and existing pavement condition.
- Partial or full slab repair. This treatment is used to repair problems such as spalling. The estimated lives of these treatments vary from 8-12 years.
- Dowel bar retrofit. Caltrans has used dowel bar retrofit as a pavement restoration strategy. This treatment is expected to be used more; however, the pool of candidates in California is considered small due to pavement age and distress levels. The estimated lives of this treatment range from 8-17 years. The dowel bar retrofit may be considered as rehabilitation strategy if the amount of repair is extensive.
- Full slab replacement. Caltrans also replaces isolated full slabs where the slab has exhibited extensive cracking or is unstable. The estimated lives of this treatment should range from 3-15 years. The full slab replacement may be considered as rehabilitation strategy if the amount of slabs to be replaced is extensive.

A summary of expected life for various treatments for rigid pavements is provided in Table 3-2. Trigger values for initiating various treatments based on national practices are also provided in the table. Work is currently underway by Caltrans to evaluate the effect of climate and traffic conditions and to develop specific trigger values for various climate and traffic conditions (Shatnawi, et al, 2006). However, proposed trigger values for use by Caltrans are based on the national values and appropriate adjustments to climate and traffic volumes. Estimated costs are provided by Caltrans Maintenance for reference only and it could vary from district to district and vary from treatment selected for each traffic condition. District Materials Engineers and/or Resident Engineers should be consulted for costs for each treatment used on a specific project.

## 3.4 DETERMINE THE FEASIBLE TREATMENT OPTIONS

Once the pavement condition has been quantified, test results collected and analyzed, and other available data are reviewed, feasible treatments can be identified. In this context, “feasibility” is determined by a treatment’s ability to address the functional and non-structural condition of the

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pavement while also meeting any future needs. At this stage of the selection process, feasibility is not a function of affordability. The primary purpose is to determine what treatments might work.

Table 3-2 Proposed trigger values and expected life for various PCC maintenance treatments (Modified from Shatnawi et al, 2006)

| Treatment | Trigger (National) | Climate Region[1] | | | | Traffic ADT | | | Life of Treatment (Year) | Estimated Cost ($)[2] |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Desert | Valley | Coastal | Mountain | <5000 | >5000;<30000 | >30000 | | |
| Crack Resealing | >1/4 inch | >1/4 | >1/4 | >1/4 | >1/4 | >1/4 | >1/4 | >1/4 | 4 - 7 | $27.7k - 42.4 k/ln mi |
| Diamond Grinding | Faulting > 1/4 inch; Ride 95 in/mile | >1/4 >190 | >1/4 >95 | >1/4 >95 | >1/4 >190 | >1/4 >190 | >1/4 >125 | >1/4 >95 | 10 - 18 | $30.0k - 80.1k/ln mi |
| Partial Slab Repair | Surface distress - Patches <1.2 $yd^2$ | <1.2 | <1.2 | <1.2 | <2.4 | <2.4 | <1.2 | <1.2 | 8 - 12 | $135 - 270/$yd^3$ |
| Isolated Slab Replacement | 3rd stage cracking or unstable slabs | Same Trigger Value. For desert, mountain, or ADT<5000, District makes decision to repair. | | | | | | | 8 - 12 | $4000 - $8000/slab |
| Dowel Bar Retrofit | LTE <60%, Faulting>1/4 inch, Max 10% Cracking | <40 >1/4 20 | <70 >1/4 10 | <70 >1/4 10 | <50 >1/4 20 | <50 >1/4 20 | <70 >1/4 10 | <70 >1/4 10 | 8 - 17 | $141k - 177k/ln mi |

Note:
[1] For locations of climate regions, see Pavement Climate Map at: http://www.dot.ca.gov/hq/oppd/pavement/guidance.htm.
[2] Estimated costs were provided by Caltrans Maintenance

A feasible alternative is one that addresses all identified distresses of the pavement (from various evaluations that are performed), provides the desired future performance over the life of the treatment, and fits within identified constraints. Some of the constraints may include:

- Construction windows.
- Traffic flow conditions.
- Overhead clearances.
- Right-of-way.
- Funding.

It should be noted that the constraints should be identified, but should not be used to eliminate treatment alternatives from consideration or development, unless the constrains indicate the treatment is not feasible.

Several treatments may be feasible for a given set of conditions. Therefore, effort should be made to identify as many feasible treatment alternatives as possible for a given project. Once the feasible treatments have been identified, the limitations of each of the options should be taken into account in relation to its suitability in comparison with the other feasible options. Treatment limitations are controlled by such factors as pavement surface deflections, pavement structural condition, roadway curvature, pavement roughness and permeability. With multiple alternatives, advantages and disadvantages of each treatment can be compared. The selection process can be used to rate

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alternatives against each other on all of the factors deemed important by Caltrans, such as initial cost, life-cycle costs, constructability, expected performance, expected life, and so on.

The information presented in Table 3-3 may be also used as a guideline for the selection of feasible treatments. This table is to target distresses commonly found in the California roadway system. The information is general in nature, and is not designed to cover either every possible rigid pavement distress or every possible treatment alternative. Some of the repair techniques have not been discussed in this report but they are mentioned so that appropriate considerations may be given during the treatment selection process, as necessary. In the table, the corrective repair techniques are defined as activities that are performed in response to the development of a deficiency or deficiencies that may negatively impact the safe, efficient operations of the pavement. Preventive techniques are to retard future deterioration, and maintain or improve the functional condition of the pavement system (without significantly increasing the structural capacity).

Table 3-3 Rigid pavement distress and related repair / preventive maintenance methods

| Distress Type | Preservation Techniques | Restoration Techniques |
|---|---|---|
| *Structural Distresses* | | |
| Transverse Cracking | Joint and crack sealing | Full-depth repair<br>Dowel bar retrofit |
| Longitudinal Cracking | Joint and crack sealing<br>Slab stabilization | Full-depth repair<br>Dowel bar retrofit |
| Corner Cracking | Joint and crack sealing<br>Edge joint resealing<br>Slab stabilization | Full-depth repair |
| Intersecting Cracking | Joint and crack sealing<br>Slab stabilization | Full-depth repair<br>Dowel bar retrofit |
| Spalling | Partial-depth repair<br>Joint and crack resealing<br>Full-depth repair | |
| Pumping | Joint and crack resealing<br>Slab stabilization | Full-depth repair<br>Dowel bar retrofit |
| Blow ups | Full-depth repairs | Joint and crack resealing |
| D-cracking (not California issue) | Partial- or full-depth repair; Joint and crack resealing | |
| *Functional Distresses* | | |
| Faulting | | Diamond grinding<br>Dowel bar retrofit<br>Slab stabilization<br>Joint and crack resealing<br>Retrofitted edge drains |
| Ride Quality | | Diamond grinding |
| Settlement | | Diamond grinding |
| Surface Polishing | Diamond grinding<br>Grooving | |
| Noise | See Caltrans website for the latest information at: http://www.dot.ca.gov/hq/oppd/pavement/qpavement.htm. | |
| Scaling | Diamond grinding | |
| Popouts | Diamond grinding | |

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The American Concrete Pavement Association (ACPA, 1998) developed trigger and limit values for jointed plain concrete pavements (JPCP), for jointed reinforced concrete pavements (JRCP) and for continuously reinforced concrete pavements (CRCP). Trigger/limit values for JPCP and JRCP are presented in Tables 3-4 and 3-5 and they may be useful when developing a feasible treatment. However, most of the concrete pavements in California consist of JPCP.

Table 3-4 Trigger and limit values for jointed plain concrete pavements (ACPA, 1998)

| Jointed Plain Concrete Pavements (Joint Space < 19.7 ft [6m])* | Trigger/Limit Values** | | |
|---|---|---|---|
| Traffic Volumes | High (ADT>10,000) | Medium (3000<ADT<10,000) | Low (ADT<3000) |
| *Structural Measurements* | | | |
| Low to high severity fatigue cracking (% of slabs) | 1.5/5.0 | 2.0/10.0 | 2.5/15.0 |
| Deteriorated joints (% of joints) | 1.5/15.0 | 2.0/17.5 | 2.5/20.0 |
| Corner breaks (% of joints) | 1.0/8.0 | 1.5/10.0 | 2.0/12.0 |
| Faulting (avg. - inch) | 0.08/0.5 | 0.08/0.6 | 0.08/0.7 |
| Durability distress (severity) | Medium-High | | |
| Joint seal damage (% of joints) | | >25/--- | |
| Load transfer (%) | | <50/--- | |
| Skid resistance | Minimum local acceptable level/--- | | |
| *Functional Measurements* | | | |
| IRI (inch/mile) | 63.4/158.4 | 76.0/190.1 | 88.7/221.8 |
| PSR | 3.8/3.0 | 3.6/2.5 | 3.4/2.0 |
| California Profilograph | 12/60 | 15/80 | 18/100 |

** Assumed slab length =15 feet.*
*** Values should be adjusted for local conditions. Actual percentage repaired may be higher if the pavement is restored several times.*

Table 3-5 Trigger and limit values for jointed reinforced concrete pavements (ACPA, 1998)

| Jointed Reinforced Concrete Pavements (Joint Space > 19.7 ft [6m])* | Trigger/Limit Values** | | |
|---|---|---|---|
| Traffic Volumes | High (ADT>10,000) | Medium (3000<ADT<10,000) | Low (ADT<3000) |
| *Structural Measurements* | | | |
| Medium to high severity transverse cracking (% of slab) | 2.0/30.0 | 3.0/40.0 | 4.0/50.0 |
| Deteriorated joints (% of joints) | 2.0/10.0 | 3.0/20.0 | 4.0/30.0 |
| Corner breaks (% of joints) | 1.0/10.0 | 2.0/20.0 | 3.0/30.0 |
| Faulting (avg. - inch) | 0.16/0.5 | 0.16/0.6 | 0.16/0.7 |
| Durability distress (severity) | Medium-High | | |
| Joint seal damage (% of joints) | | >25/--- | |
| Load transfer (%) | | <50/--- | |
| Skid resistance | Minimum local acceptable level/--- | | |
| *Functional Measurements* | | | |
| IRI (inch/mile) | 63.4/158.4 | 76.0/190.1 | 88.7/221.8 |
| PSR | 3.8/3.0 | 3.6/2.5 | 3.4/2.0 |
| California Profilograph | 12/60 | 15/80 | 18/100 |

** Assumed slab length = 33 feet.*
*** Values should be adjusted for local conditions. Actual percentage repaired may be higher if the pavement is restored several times.*

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## 3.5 COMPARE THE FEASIBLE OPTIONS

It is likely that several maintenance or repair treatments may be identified as feasible. When comparing these different treatments, thought should be given to the treatment placement cost, and the life of the treatment. Additional factors to consider when analyzing and comparing treatment options include: cost effectiveness, traffic level, construction windows or limitations, and other factors, such as weather, curing times or local issues that affect a specific treatment. The most desirable treatment is the one that provides the greatest benefit (whether that benefit is measured in terms of improvement in condition, extension of pavement life, or even, more simply, the life of the treatment) for the lowest life cycle costs. At this point, a life cycle or other cost effectiveness measure should be performed.

### *3.5.1 Life Cycle Costing*

Life-cycle cost analysis (LCCA) is an analytical technique that is built upon principles of economics to evaluate long-term alternative investment options. It is a useful tool for comparing the value of alternative treatments. In the LCCA, all costs associated with a feasible treatment or alternative could be compared based on the present value (PV) or equivalent uniform annual cost (EUAC).

The LCCA typically involves the following steps:

- Establish alternative/treatment;
- Determine analysis period;
- Determine discount rate;
- Determine maintenance/rehabilitation treatment frequencies;
- Estimate both agency and user costs;
- Calculate LCC; and
- Select treatment/alternative.

Caltrans is currently developing a pavement life-cycle cost analysis procedure based on the RealCost model developed by FHWA (FHWA, 1998). A draft user manual has been prepared (Caltrans, 2006). The user manual provides descriptions of the LCCA methodology, the use of the RealCost software, and examples of LCCA. The user manual also includes the following information:

- Typical maintenance and rehabilitation schedule for California;
- Maintenance and rehabilitation cost estimation;
- Maximum queue length estimation;
- State highway traffic hourly distribution;
- Agency construction unit costs (by district); and
- Work zone/traffic inputs determination.

It is anticipated that the development of the LCCA procedure will be completed in 2007. At this time, it would be possible to perform LCCA for various treatments for a variety of conditions.

### *3.5.2 Compare and Select Options*

Typically, a treatment/alternative with the lowest LCC is chosen; however, there are other factors that should be taken into consideration when making a final decision. These factors include the following:

- Agency policies.

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- Overall pavement management of network (policies).
- Provisional (staged) construction.
- Traffic control requirements (safety and congestion).
- Available lane closure time.
- Existing geometric design problems and constraints that may prevent a treatment to be used.
- Right-of-way restrictions that may prevent a treatment to be used.
- Regulatory restrictions.
- Available materials and equipment.
- Contractor expertise and manpower for the location.
- Construction considerations (duration of construction).
- Conservation of materials and energy by using recycled materials.
- Potential climatic issues/constraints.
- Performance of treatment elsewhere under similar conditions.
- Availability of local materials and contractor capabilities.
- Worker safety during construction.
- Incorporation of experimental features.
- Municipal preference, local government preference, and recognition of local industry.
- Project funding and scope.

A simple ranking procedure, as one described in the FHWA NHI Course 131062 (FHWA, 2001) http://www.nhi.fhwa.dot.gov/, may be developed to rate each feasible treatment/option. Factors to be considered in the ranking procedure should include key factors such as initial cost, life cycle cost, expected life of the treatment, user costs, and Caltrans experience with the feasible treatment. The importance of each factor can be signified by assigning a weighting to it. The weighing value represents the relative importance of a factor in all factors considered and could be on a scale of 1 to 10 or 1 to 100. The weighting could be assigned either by an individual or by groups of managers and other decision makers with a direct knowledge of the project and/or a stake in the outcome.

Each feasible treatment option is then rated independently against the key factors using a uniform scale, such as 1 to 5 or 0 to 100. The highest rating means that treatment option best meets that criterion. The score of factor is calculated by multiplying the weights for each factor by the rating assigned. The total score for each treatment is the sum of the individual scores. The alternatives are then ranked in order, from the highest score to the lowest; the treatment option with the highest score is selected. Table 3-6 shows an example of this process.

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Table 3-6 Example worksheet of a selection process incorporating multiple selected decision factors and assigned weightings. (FHWA, 2001)

| Decision Factor Names ⇨ | DECISION FACTORS | | | | | | Total Score | Rank |
|---|---|---|---|---|---|---|---|---|
| | Initial Cost | Life Cycle Costs | Expected Life | Ease of Repairing/ Maintaining | Construction Traffic Control | Proven Design in Agency | | |
| Weightings ⇨ | 25 | 15 | 20 | 15 | 10 | 15 | | |
| Alternative 1 | 60 / 15 | 60 / 9 | 100 / 20 | 80 / 12 | 90 / 9 | 100 / 15 | 80 | 1 |
| Alternative 2 | 60 / 15 | 60 / 9 | 100 / 20 | 80 / 12 | 90 / 9 | 100 / 15 | 80 | 1 |
| Alternative 3 | 60 / 15 | 60 / 9 | 70 / 14 | 50 / 7.5 | 60 / 6 | 40 / 6 | 57.5 | 6 |
| Alternative 4 | 60 / 15 | 60 / 9 | 70 / 14 | 50 / 7.5 | 60 / 6 | 40 / 6 | 57.5 | 6 |
| Alternative 5 | 60 / 15 | 40 / 6 | 100 / 20 | 80 / 12 | 100 / 10 | 90 / 13.5 | 76.5 | 3 |
| Alternative 6 | 60 / 15 | 80 / 12 | 40 / 8 | 20 / 3 | 40 / 4 | 20 / 3 | 45 | 9 |
| Alternative 7 | 40 / 10 | 60 / 9 | 40 / 8 | 50 / 7.5 | 50 / 5 | 30 / 4.5 | 44 | 10 |
| Alternative 8 | 70 / 17.5 | 80 / 12 | 60 / 12 | 50 / 7.5 | 80 / 8 | 40 / 6 | 63 | 5 |
| Alternative 9 | 100 / 25 | 100 / 15 | 20 / 4 | 20 / 3 | 40 / 4 | 40 / 6 | 57 | 8 |
| Alternative 10 | 30 / 7.5 | 60 / 9 | 100 / 20 | 100 / 15 | 100 / 10 | 30 / 4.5 | 66 | 4 |

## 3.6 KEY REFERENCES

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